CONSEIL PERMANENT INTERNATIONAL POUR
L'EXPLORATION DE LA MER
34B STRANDVEJ, HELLERUP-DANEMARK

RAPPORTS
ET
OCÈS-VERBAUX DES RÉUNIONS

VOLUME XCV

REPORTS OF THE PROCEEDINGS OF
SPECIAL PLANKTON MEETING HELD ON MAY 27TH, 1935, AT COPENHAGEN
AND OF
THE SPECIAL MEETING HELD AT VIDENSKABERNES SELSKAB'S
PREMISES ON MAY 31ST, 1935.

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

Octobre 1935.

PREFACE

During the Meeting of the International Council for the Exploration of the Sea at the end of May 1935 a number of lectures on various subjects were given at two Special Meetings held during the week of the session.

On Monday, May 27th, a Special Plankton Meeting was held at "Eltham" on which occasion Mr. F. S. Russell of Plymouth, Professor A. C. Hardy of Hull and Mr. S. Landberg of Bornø lectured on the questions recorded in the list of contents below.

On May 31st a Meeting was held at the premises of the "Kongelige Danske Videnskabernes Selskab"; on this occasion Professor B. Schulz of Hamburg reported on some results obtained from the Kattegat investigations of internal waves undertaken in 1931 (a summary of this lecture also appears in the following pages). Further Professor Johan Hjort of Oslo lectured on "Fishing Experiments and Administrative Problems". Professor Hans Pettersson of Gothenburg demonstrated a film showing internal waves originating from the action of an oscillating magnetic force in a paramagnetic fluid. Professor N. Zeilon of Lund demonstrated internal waves produced in a whipping trough with water layers of different densities.

TABLE OF CONTENTS

Page

I. A Review of some Aspects of Zooplankton Research, by F. S. Russell, Plymouth 3

II. Further Investigations upon the Photosynthesis of Phyto-plankton by constant Illumination, by H. Höglund and S. Landberg, Bornø .. 31

III. The continuous Plankton Recorder: a new Method of Survey, by A. C. Hardy, Hull 35

IV. Die Ergebnisse der internationalen hydrographischen Beobachtungen im Kattegat im August 1931, by B. Schulz, Hamburg 49

A REVIEW OF SOME ASPECTS OF ZOOPLANKTON RESEARCH.

BY

F. S. RUSSELL,

Naturalist at the Plymouth Laboratory of the
Marine Biological Association of
the United Kingdom.

now nearly one hundred years since the net was first introduced by Johannes ller (1846). Zoology was still in its scriptive stage and a rich ground for the tion of new species was thus opened up. nat time also the theory of evolution was g concrete form, to be firmly established publication of Darwin's "Origin of in 1859. The evolutionary theory was the ecting force for the study of embryology, he development of this branch of zoology, on plankton animals has played a greater n that on any other population of the kingdom. We owe to the labours of the s of the latter half of last century most present knowledge on the affinities and classification of the major groups of in- e animals. With the exception of insects, rtebrates are essentially inhabitants of the almost all spend the earlier stages of their fting in the water layers in the plankton ity.

ng the first workers in this line of research H. Huxley who sailed in 1846 in the nake" to Australian waters. In these days rate and costly apparatus it is well to bear what far reaching results can be obtained simplest means. Huxley used as his bag of the bunting of which flags are With this simple net he sieved the sea at vailable opportunity. As a result he rated the true position of the medusae and hores in the coelenterate kingdom, and ed the affinities of the pelagic tunicates ssile ascidians of our sea shores. Of even reaching importance was the result of his ion of the medusae whereby he indicated ence and importance of the germ-layers in lopment of metazoa.

o-day I do not wish to take as my theme nination of plankton animals with the aim of elucidating problems purely ogical or embryological in nature. I wish o review those aspects of zooplankton whose concern has been the study of animals as members of a community, and part they play by their habits and e in the balance of life in the sea. The ill be concerned only with metazoa.

In reviewing the present position I shall try to embrace all the aspects of the situation. It is necessary to take the wide view without unduly stressing any particular problem, because we have suffered in the past from a tendency to pursue certain directions of enquiry to a disproportionate extent. As a result plankton research has become somewhat uncoordinated, and advance has been held up by a lack of consideration as to which are the problems that require special attention in order to bring our various fields of knowledge into line.

With such a wealth of data scattered amongst the biological literature of the world the task of review becomes impossible unless we first fix upon certain outstanding events around which the main sequence of the review can be evolved.

I have adopted the following landmarks as representative of the sequence of events after the introduction of the quantitative method by Hensen, leading to the publication of his Methodik (1895)

1. The Plankton Expedition in the "National" under the leadership of Hensen in 1889.
2. The comprehensive scheme for the collection of plankton throughout the North Sea and adjacent waters of the Atlantic, Channel and Baltic, during the years 1902 to 1908 by the International Council.
3. The completion by Lohmann in 1906 of a year's detailed survey of the total plankton production at Laboe in Kiel Bay.

During these two latter periods plankton study received a constant leavening element in the intensely biological outlook of Professor Gran.

4. The post-war period.

Three publications previous to the last period should also be mentioned as having left their mark in the history of plankton research and stimulated many workers, these were Adolf Steuer's "Planktonkunde" published in 1910; "Conditions of Life in the Sea" by James Johnstone, in 1908 and the "Depths of the Ocean" by Murray and Hjort in 1912.

I have taken these four periods because they illustrate the main problems that confront those concerned with zooplankton research. The first is the necessity of knowing the distribution and abundance of the plankton in the open ocean.

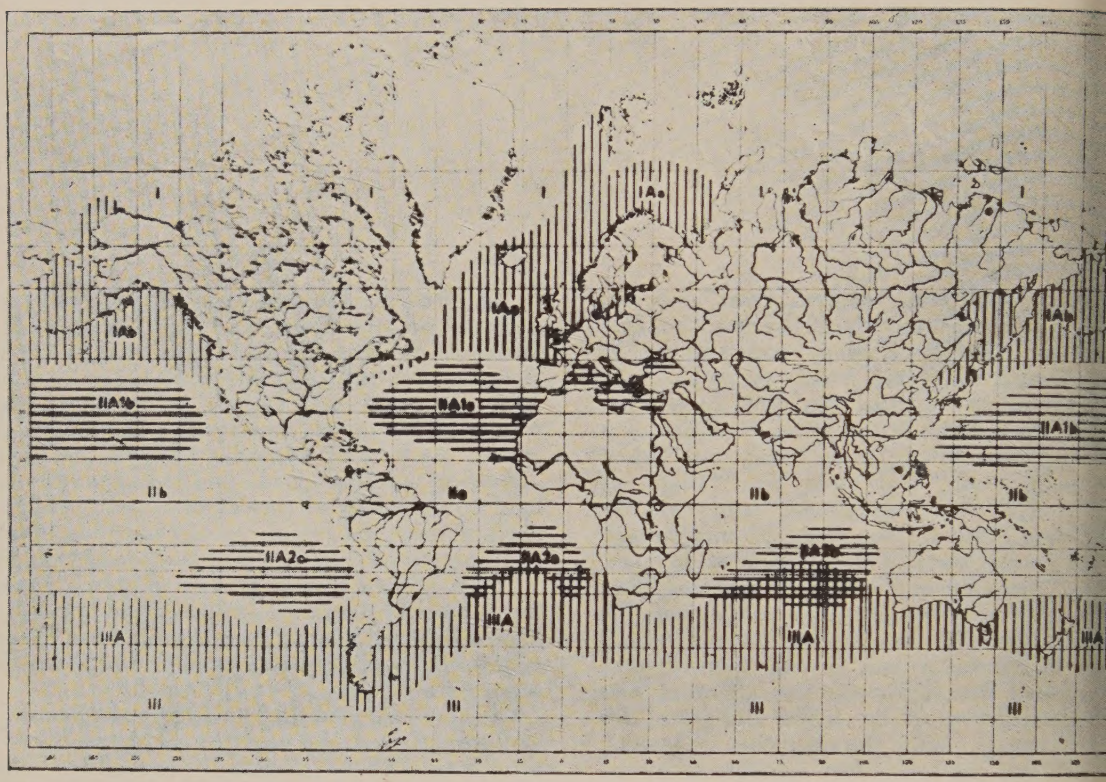


Fig. 1.

Distribution regions of oceanic plankton organisms (after Steuer, 1933, p. 292, Fig. 8, for Copepods). explanation see Text.

Secondly comes the desire for a similar knowledge of the conditions in the coastal waters whose origin and movements are so largely governed by the oceanic circulation. In intimate connexion with this is the use of our knowledge of the plankton distribution as an aid to the interpretation of hydrographical data. Thirdly, knowing something of the animals' distribution we need to know about their relations with their animate and inanimate environment, and the causes of their fluctuations in abundance. This is a work that has so far only been attempted in coastal waters where the necessary observations can be made at frequent intervals throughout the year with the facilities of a laboratory close at hand. And finally the research has shown the need for even more detailed observations, for a close study of life-histories and habits, and for the examination of the more specialised problems that have arisen such as the relations between the plankton and the fish that are used as food by man.

Before any work on the biology of animals can be attempted the animals that we wish to study must be described and classified. This is a task that has gone on from the earliest days of marine biology and as regards the zooplankton mu our present knowledge has been built up fr results of the collections of the great o graphical expeditions. Many years must before the description of all the species of pl animals is brought to completion. We can h say with gratitude to the workers in the pa in many groups today the necessary knowle reaching its final stages. Coincident wit descriptive work our knowledge of geogra distribution has grown and as the groups been better known the distribution of the s among their faunistic regions has become detailed.

It is probable that in ocean waters one main barriers to distribution is that of th perature conditions. Animals adapted for s ful reproduction in any given temperature will be carried in the water masses and current systems so far as the necessary tempe conditions are maintained.

When the temperature conditions have taken into consideration the chief clues geographical distribution of the species are found in the systems of oceanic circulation

now be divided into definite masses of different characteristics. These different constantly moving and are separated nother by regions of mixed water which de or narrow according to the locality. ns are the antarctic, the subtropical and l convergences in the south, and the regions in the north which vary from es with well defined boundaries between cold waters in the west to the wide- ing regions in the east. Each body of ts own somewhat characteristic plankton fferent levels. These faunas tend to mix daries, some species of the colder water nder favourable conditions found at ls. Thus the distribution of the arctic fauna dips beneath the surface layers south.

ent work on the geographical distribution s Steuer (1933, p. 291) has adopted ng scheme, (Fig. 1).

n-polar Arctic.
Sub-arctic (temperate, northern transitional, or boreal)
a. Atlantic.
b. Pacific.
n-equatorial tropical.
a. Atlantic.
b. Indo-pacific.
Sub-tropical
. Northern sub-tropical.
a. Atlantic (and Mediterranean — Black Sea)
b. Pacific.
2. Southern Sub-tropical.
a. Atlantic.
b. Indian.
c. Pacific.
n-polar Antarctic.
Circum-polar Sub-antarctic (southern transitional).

ver possible to confine living organisms limits of precise schemes, and while ssification is convenient the boundaries d for all species. The most important ctor is probably temperature and each y have its own limits. There is thus p in the limits of distribution of species sition zones; this has been made clear k of the Discovery Expedition in the lantic (Mackintosh, 1934). Yet in ere the transition in temperature is d amounts to several degrees, many d their limits, and the faunas of the g water masses become clearly de-

many groups the majority of species lly described it should be the aim of editions to make our knowledge of geographical distribution more complete. The data thus obtained will act as bench-marks for the study in years to come of the secular changes in the water movements of the ocean. With this idea in mind I have produced a preliminary table (Table I) giving the number of known species in the more important plankton groups and their subdivision into broad geographical areas. It has only been possible to produce such a table with the cooperation of many specialists in plankton animal groups. I owe a debt of gratitude to the following workers for their very willing and painstaking assistance.

Dr. S. T. Burfield (Chaetognatha); Mr. G. P. Farran (Copepoda); Professor P. Fauvel (Tomopteridae); Miss A. B. Hastings (Tunicata); Dr. P. L. Kramp (Medusae); Professor Th. Mortensen (Ctenophora); Dr. K. Stephensen (Amphipoda); Professor W. M. Tattersall (Euphausiacea); Mr. A. K. Totton (Siphonophora).

The production of this table brings out some points of interest.

1. The greater number of cold water species in the south as opposed to the north.
2. The phenomenon of epiplanktonic[1]) bipolarity.
3. The small number of purely sub-antarctic species of copepods and perhaps other groups.
4. Differences between the faunas of the different oceans.
5. The inequality in the state of our knowledge on different groups.

In all groups (except the meroplanktonic medusae and the essentially bottom living Gammarid Amphipods) the preponderance of southern over northern cold water species is evident. This fact has been remarked on by Meisenheimer, (1905, p. 90) for the pteropods. He suggests an obvious cause in pointing to the much greater area of confluence between warm and cold waters in the south than in the north as conducive to the opportunity for increased evolution of species from the warm species-producing centre. But there is an added factor that our increased knowledge of oceanic circulation brings to light both on this problem and that of bipolarity. Before proceeding it should be pointed out that Steuer (1933, p. 284) has suggested that there are no truly arctic Gymnoplean Copepods, but that the arctic and sub-arctic regions should be taken together. He gives as an example *Calanus hyperboreus,* a species that has been

[1]) In my original manuscript I had used the word "bipolar"; it was however pointed out to me by Dr. H. B. Bigelow that the original meaning of this word implied discontinuous bipolarity (see also Stiasny, 1934); it is necessary to find some other term and I have used "bipolar-epiplanktonic" as denoting that these species occur in the surface waters in north and south, though when present in warm latitudes they are mesoplanktonic.

(Continued on page 12).

and meroplanktonic coelenterates.

	Arctic	Arctic-Boreal and Boreal	Antarctic	Sub-antarctic	Bipolar-epiplanktonic	Cosmopolitan	Warm	Deep Sea	TOTAL
COELENTERATA									
Antho-, Lepto-, and Scyphomedusae[1]	20	100	10	15	—	—	370	20	535
Trachy- and Narcomedusae[1]	4	10	3	6	—	—	90	21	134
Siphonophora									
Calycophorae	—	—	2		1	—	64	5	72
Physophorae	—	?1	2		—	—	29	2	34
Ctenophora	1	2	2	1	—	2	69?	3	80?
NEMERTEA	—	—	—	—	—	—	—	34	34
POLYCHAETA									
Tomopteridae	—	?1	?4		1	—	38	?	44
CHAETOGNATHA	—	2	2		2	—	18	6[2]	30
CRUSTACEA									
Cladocera	—	1	—	—	(3)	—	3	—	7
Copepoda	7	10	32	5	1(5)	10	489	195[3]	754
Amphipoda									
Hyperiidea	2	—	10	—	—	2	250	28[4]	292
Gammaridea	7	—	—	—	—	—	20	17[4]	44
Euphausiacea	—	6	2	7	(1)	—	46	23	85
MOLLUSCA									
Pteropoda									
Thecosomata	—	—	2		1(1)?	—	44	3	51
Gymnosomata	—	1	2		(1)?	—	37	?	41
Heteropoda	—	—	—	—	—	—	90	—	90
TUNICATA									
Appendicularia	2	1	6		—	1	48	3	61
Thaliacea									
Doliolidae	—	—	1?		—	—	11	—	12
Salpidae	—	—	1		—	—	24	—	25
Pyrosomidae	—	—	—	—	—	—	8	—	8
TOTAL	178		115		17	15	1754	360	2433
(Excluding meroplanktonic Medusae	58		90		17	15	1378	340	1898)

	In 3 oceans	Atlantic and Indian	Atlantic and Pacific	Indian and Pacific [1])	Atlantic only [2])	Indian only	Pacific only	Mediterranean only	TOTAL
COELENTERATA									
Antho-, Lepto-, and Scyphomedusae	11	4	21	32	160	60[3]	100	?	
Trachy- and Narcomedusae	15	3	5	4	45	9[2]	17	?	
Siphonophora									
Calycophorae	24	—	8	15	9	1	4	—	61
Physophorae	10	1	2	9	4	—	3	—	29
Ctenophora	2	—	—	10	24	4	16	9	65
NEMERTEA									
POLYCHAETA									
Tomopteridae	3	1	3	3	6	7[4]	8	7	37
CHAETOGNATHA	9	1	—	4	3	—	1	—	18
CRUSTACEA									
Cladocera	3	—	—	—	—	—	—	—	3
Copepoda	146	30	58	57	106	27	65[6]	?	489
Amphipoda[7]									
Hyperiidea	54	30	23	1	83	26	26	7	250
Gammaridea	3	1	2	—	10	3	1	—	20
Euphausiacea	14	1	4	4	11	2	16	?2	52
MOLLUSCA									
Pteropoda									
Thecosomata	24	2	3	2	7	1	3	2	44
Gymnosomata	5	2	1[5]	6	12	2	5	4	37
Heteropoda	8	4	6	16	27	3	9	17	90
TUNICATA									
Appendicularia	9	7	—	2	20	1	3	5	47
Thaliacea									
Doliolidae	6	3	—	—	1	1	1	—	12
Salpidae	15	3	—	1	2	2	1	—	24
Pyrosomidae	3	2	—	—	—	3	—	—	8

1st column.
( ) = Bipolar sub-arctic and sub-antarctic.
[1] Approximate Numbers.
[2] Mesoplankton — below 100 fathoms and mostly deeper.
[3] Below 200 fathoms, mostly not found in epiplankton at night.
[4] At least 300—500 m. wire out.

2nd column.
[1] Including Indo-Pacific Region (Siboga).
[2] Including Atlantic-Mediterranean.
[3] Including Siboga results.
[4] Six in Red Sea only.
[5] Pacific and Mediterranean.
[6] Including Indo-Pacific (Siboga).
[7] Siboga results divided between Indian and Pacific according to localities.

NOTES TO TABLE I.

following definitions have been used:—

ar-epiplanktonic. Those species which are
d in surface layers in northern and southern cold
ers but when present are found only in deep layers
warm latitudes.

opolitan. Those species which are found alike
urface warm and cold waters.

Sea. Those species living below a depth of about
fathoms, that is below the limit of penetration of
t. The inhabitants of this region have been regarded
many as likely to be found to be cosmopolitan. They
e not been divided among the oceans in Table I as
many groups our knowledge of the true deep sea
ies is insufficient.

hose groups in which the division of species between
and sub-arctic, and antarctic and sub-antarctic, is
in the numbers in the Table have been placed
y between the two columns in each region. Below
ave been written arctic-subarctic, and antarctic-sub-
c.

ENTERATA

The data for Medusae have been supplied by
P. L. Kramp. The Medusae have been divided
the Mero-planktonic Antho-, Lepto-, and Scypho-
usae, and the Holo-planktonic Trachy-, and Narco-
usae.

ONOPHORA. The data have been obtained
Moser, 1925; Bigelow, 1911 and 1931; and
s and van Riensdijk, 1908, with the
stance of Mr. A. K. Totton.

cold water species are:—
arctic, *Stephanomia cara* (A. Agassiz).
rctic-sub-antarctic, *Diphyes antarctica* Moser; *Cry-
tallophyes amygdalina* Moser (? deep sea), *Pyroste-
hos vanhöffeni* Moser, and *Stephanomia convoluta*
Moser.
lar, *Dimophyes arctica* Chun.

still uncertain whether *Stephanomia cara* should be
d as a distinct species from the warm water
omia bijuga (della Chiaje).

following are possibly deep-sea species, *Chuniphyes
ntata* Lens u. v. R., *Chuniphyes problematica* Moser,
hyes ovata (Kef. u. Ehl), *Thalassophyes crystallina
Amphicaryon acaule* Chun, *Pterophysa (Bathyphysa)*
Lens u. v. R., and *Bathyphysa sibogae* Lens u. v. R.

OPHORA. The data have been supplied by
H. Mortensen, and the distribution in the
ns has been taken from Moser (1909). The cold
r species are:—
Arctic, *Mertensia ovum* Fabr.; Arctic and sub-arctic,
Pleurobrachia crinita Moser and *Bolina infundibulum*
Martens; Sub-antarctic, *Callianira antarctica* Chun;
Antarctic, *Callianira cristata* Moser and *Beroe
ompacta* Moser.
e cucumis Fabr. and *Pleurobrachia pileus* Fabr.
oth in the arctic and antarctic, but also in surface
of warm latitudes and are cosmopolitan.
ser (1909, p. 181) was of the opinion that the
ores in cold waters have undoubtedly evolved from
e of species formation in warm waters.

deep sea species are *Bathyctena chuni* (Moser),
ctena acuminata Mrtsn., and *Beroe abyssicola* Mrtsn.

NEMERTEA. The Pelagic nemerteans are after Brinkmann (1917) and Wheeler (1934).

POLYCHAETA.

Tomopteridae. The data have been supplied by Prof. P. Fauvel.

The cold water species are:—

Sub-arctic, ? *Tomopteris helgolandica* Greef.

Antarctic-sub-antarctic, *Tomopteris carpenteri* Quatref., *T. rosea* Ehlers, ? *T. opaca* Treadwell, and ? *T. tentaculata* Treadwell.

T. septentrionalis Quatref. is regarded by Augener (1929, p. 281) as a bipolar species.

CHAETOGNATHA. The data have been supplied by Dr. S. T. Burfield. Ritter-Zahony's (1911) mesoplankton species have been regarded as deep sea. The cold water species are as follows:—

Antarctic-sub-antarctic, *Heterokrohnia mirabilis* Ritt.-Z. and *Sagitta gazellae* Ritt.-Z.; Bipolar, *Sagitta maxima* (Conant) (and deep sea), *Eukrohnia hamata* Möb.

S. gazellae and *S. maxima* are both very nearly related to the warm water species *S. lyra* Krohn. If they can be regarded as separate species, it is possible that *S. gazellae* has evolved in southern cold waters; and that *S. maxima* has evolved in cold northern waters and become bipolar. *S. planctonis* Steinhaus a deep water species appears in the Antarctic.

To the number of warm water species should also be added six species described by Oye (1918) from the Java Sea whose identity has not yet been confirmed, and *S. euxina* from the Black Sea. The deep-sea species are *Sagitta decipiens* Fowl., *S. lyra* Krohn, *S. macrocephala* Fowl., *S. planctonis* Steinhaus, *Eukrohnia fowleri* Ritt.-Z., and *Heterokrohnia mirabilis* Ritt.-Z.

Crustacea

CLADOCERA. The data have been taken from Rammner (1933). There are no purely arctic or ant-arctic cladocera, Sub-arctic, *Podon intermedius* Lillj.; Bipolar (sub-arctic and sub-antarctic) *Podon leuckarti* G. O. Sars, *Podon polyphemoides* Leuck., and *Evadne nordmanni* Lovén.

COPEPODA: all the data for copepods have been supplied by Mr. G. P. Farran.

The following is the tentative list of cold water and cosmopolitan species:—

Arctic and Boreal. *Calanus cristatus, Calanus hyperboreus, Pseudocalanus elongatus, Microcalanus pusillus, Gaidius brevispinus* (A), *Pareuchaeta glacialis* (A), *Pareuchaeta norvegica* (B), *Undinopsis similis, Undinella oblonga* (A), *Scolecithricella minor* (B), *Scolecithricella dentata, Temorites brevis, Heterorhabdus norvegicus* (B), *Augaptilus glacialis* (A), *Mormonilla polaris* (A), *Oncaea borealis* (A), *Acartia longiremis* (A).

Antarctic. *Calanus propinquus, Calanus acutus, Rhincalanus gigas, Stephus antarcticus, Chiridius antarcticus, Chiridius minor, Chiridius polaris, Gaetanus antarcticus, Euchirella rostromagna, Undeuchaeta spectabilis, Pareuchaeta austrina, Pareuchaeta erebi, Pareuchaeta rasa, Pareuchaeta antarctica, Pareuchaeta similis, Xanthocalanus tenuiserratus, Onchocalanus frigidus, Cephalophanes frigidus, Scolecithricella glacialis, Scaphocalanus impar, Scaphocalanus sub-brevicornis, Amallothrix*

polaris, Amallothrix incisa, Racovitzanus antarcticus, Metridia gerlachei, Metridia curticauda, Heterorhabdus austrinus, Heterorhabdus pustulifer, Haloptilus ocellatus, Paralabidocera hodgsoni, Oithona frigida, Oncaea curvata.

Sub-antarctic. *Calanus simillimus, Eucalanus longiceps, Clausocalanus laticeps, Pareuchaeta biloba, Candacia cheirura.*

Bipolar. *Microcalanus pygmaeus, Scaphocalanus magnus, Metridia lucens, Metridia longa* (A), *Heterorhabdus compactus, Candacia falcifera.*

Cosmopolitan. *Calanus finmarchicus, Ctenocalanus ranus, Gaidius tenuispinus, Scaphocalanus brevicornis, Pleuromamma robusta, Pleuromamma borealis, Heterostylites longicornis, Oithona similis, Oncaea notopus, Oncaea conifera.*

A. With a tendency to be purely arctic.
B. With a tendency to be purely boreal.

AMPHIPODA. The data have been supplied by Dr. K. Stephensen.

Hyperiidea.

The cold water species are:—

Arctic, *Themisto libellula* (Mandt), *T. abyssorum* (Boeck) (mainly); Antarctic (? subantarctic), *Mimonectes setosus* Barnard, *Vibilia edwardsi* Bate, *Cyllopus lucasi* Bate, *Janira macrocephala* Dana, *Hyperoche capucinus* Barnard, ? *Hyperia macromyx* Walker, *Hyperiella dilatata Stebb., Euprimno antartica* Stebb., ? *Brachyscetus antipodes* Bate, (*Hyperoche lutkenoides* Walker, and *H. cryptodactylus* Stebb. uncertain species).

Paralanceola anomala Barnard, and *Hyperiella antarctica* Bovall. are deep sea antarctic species.

Cosmopolitan, *Scina borealis* G. O. Sars, *Themisto gaudichaudi* Guer.

In addition to the 28 deep sea species given in Table I there are a further 25 species which should probably be regarded as deep sea. The number of warm water species would thus be proportionately reduced.

Gammaridea.

The cold water species are:—

Arctic-subarctic, *Cyclocaris guilelius* Chevreux (deep sea), *Pseudolibrotus glacialis* (G. O. Sars), *P. nanseni* (G. O. Sars), *Orchomonella lobata* Chevr. (deep sea), *Apherusa glacialis* (H. J. Hansen), *Eusirus holmi* H. J. Hansen, *Cleonardo microdactylus* K. Steph. (? deep sea,) *Hyperiopsis voringi* G. O. Sars, (deep sea).

EUPHAUSIACEA: the data have been supplied by Prof. W. M. Tattersall.

The cold water species are as follows: —

Antarctic, *Euphausia superba* Dana and *Euphausia crystallorophias* H. & T.; sub-antarctic, *Euphausia frigida* Hansen, *E. vallentini* Stebbing, *E. triacantha* Holt & Tattersall, *E. longirostris* Hansen, *E. hanseni* Zimmer, *Thysanoessa macrura* G. O. Sars, and *T. vicina* Hansen.

Thysanoessa gregaria G. O. Sars is bipolar in sub-arctic and sub-antarctic regions of the north and south Atlantic and north and south Pacific.

The genera *Euphausia* and *Thysanoessa* are cosmopolitan and upper layer genera on the whole. It seems likely that the cold water forms have evolved from the warm water species of the upper layers, as they are more nearly relat to upper layer warm water species than to deep sea speci

PTEROPODA. Data taken from Meisenheim (1905), Tesch (1904), Bonnevie (1913), Mas (1920), and Pruvot-Fol (1924).

Thecosomata. The cold water species are: —

Antarctic-sub-antarctic, *Limacina (Clio) australis* Eydo and Souleyet; Sub-antarctic, *Cleodora sulcata* (Pf fer) (See Mackintosh, 1934, p. 86) (*Limacina a arctica* Woodward has not been included sin Meisenheimer suggested that its separation fr *L. helicina* was not certain).

Bipolar, *Limacina helicina* Phipps.

Large numbers of *L. helicina* from the antarctic w examined by Massy (1920) and no reasons were fou for regarding the arctic and antarctic forms as differ *Limacina balea* Möller may be bipolar in sub-arctic a sub-antarctic waters.

There are at least three deep sea species:— *Peraclis diversa* Mont., *Limacina helicoides* Jeffre and *Clio falcata* Pfeffer.

Gymnosomata. The cold water species are:— Arctic and sub-arctic, *Clione limacina* Phipps; A arctic and sub-antarctic, *Clione antarctica* E. A. Smi Sub-antarctic, *Spongiobranchaea australis* d'Orbigny (S Mackintosh, 1934, p. 86).

Clione limacina has been regarded as bipolar, but Mas (1920) regards the antarctic form *C. antarctica* to " entitled to specific rather than varietal rank".

Heteropoda. The data have been taken from Tes (1906). There are no purely cold water species.

TUNICATA: The data have been supplied by M A. B. Hastings.

Appendicularia: (supplemented from Lohmann a Bückmann (1926).

The cold water species are as follows:— Arctic, *Oikopleura vanhöffeni* Lohm. and *Oikople chamissonis* Mertens; Arctic boreal, *Oikople labradoriensis* Lohm.; Antarctic-subantarctic, *Oi pleura gaussica* Lohm., *O. valdiviae* Lohm., *O. d galski* Lohm., *O. weddelli* Lohm., *Fritillaria a arctica* Lohm. and *Fritillaria drygalski* Loh Cosmopolitan, *Fritillaria borealis* Lohm., with sev forms; Deep Sea, *Fritillaria aberrans* Lohm. *Cha pleura mirogaster* Lohm., and *Bathycordaeus cha* Chun are possibly purely deep sea species (L mann, 1931, p. 108).

In his Weddell Sea report Lohmann (1928, p. gives the distribution of certain species as still uncert these have been included here with the warm w species.

Lohmann (1905) has shown that the polar spe of Oikopleura are the most recently developed. For t origin he favoured Ortmann's hypothesis that they are remains of a universal warm water population left at poles when climatic changes set in, and which have s developed their own peculiar species. On the contrary regarded *Fritillaria borealis* as the relic of the orig polar stock which has given rise to warm water spe

Whatever the origin of the Oikopleura species in p waters it is at any rate certain that there are no bip species. The Oikopleuras are essentially inhabitants of upper layers and are dependant on the nannoplankton their food supply. It is thus unlikely that any w survive sufficiently long in the deepest layers to

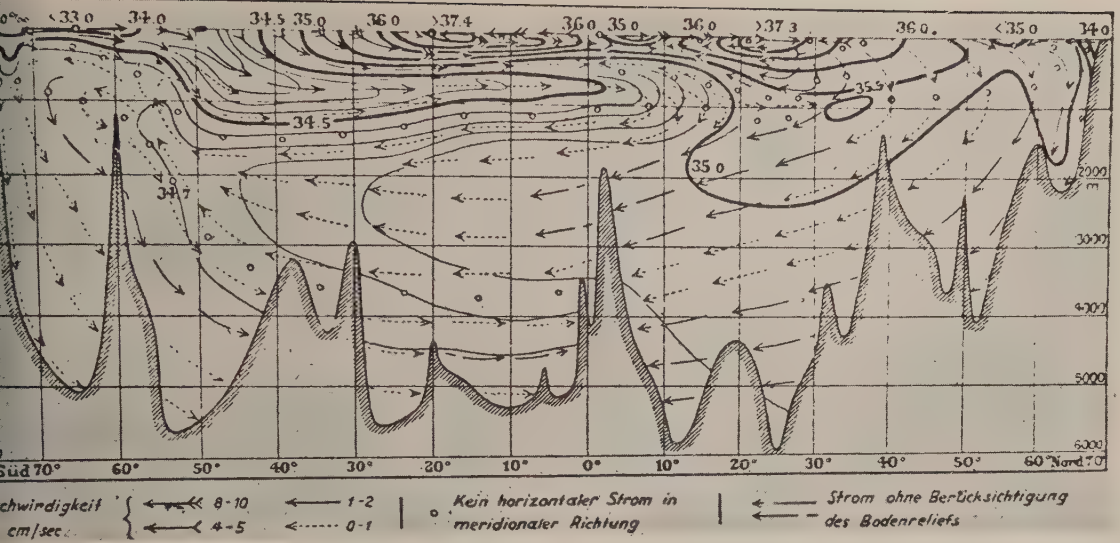


Fig. 2.

rculation of the meridional component of the water movements in the Atlantic Ocean at 30° W. (after Defant, 1927, p. 365, Fig. 53).

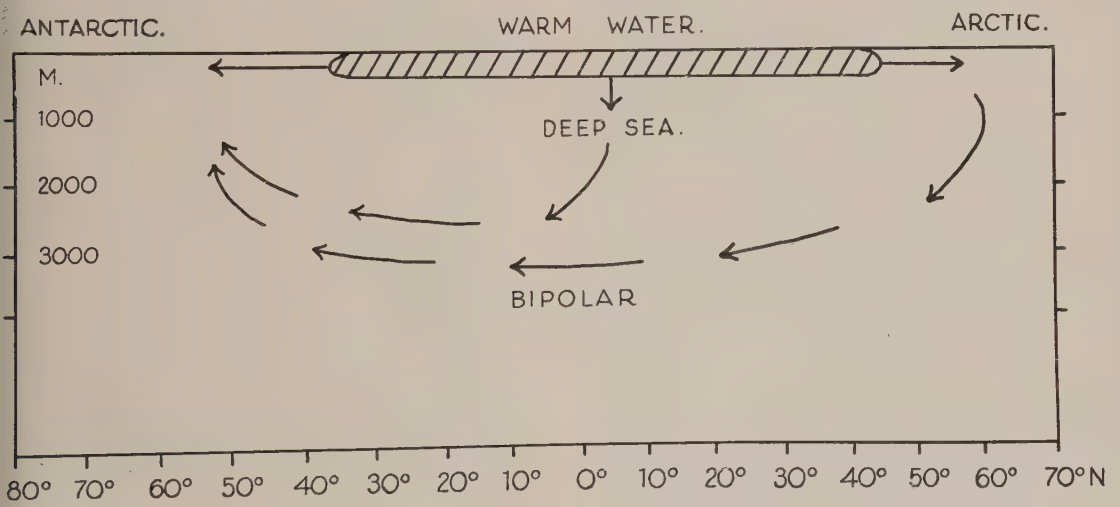


Fig. 3.

n showing how cold water species that have evolved from warm water species in the Northern hemisphere will be carried southwards in deep water to become bipolar-epiplanktonic. Species which have evolved as deep sea and become adapted to low temperatures may also thus join the Antarctic community. The diagram is based on the circulation of water given in Figure 2.

transport from the north polar regions to the ic. Lohmann (1931, p. 45) remarks however on narkable similarity between the northern *O. labra-is* and the southern species *O. gaussica* and *O. val-* and suggests that they may be regarded as a group of species in the genus Oikopleura. *galski* on the other hand is most nearly related to rm water species *O. albicans*.

illaria borealis may on the other hand be a relic ages left at both poles as Lohmann suggested. If so it seems strange that they have not given rise to peculiar to the poles. Another polar species *rtica* Lohm., is confined to the Antarctic and has nown by Lohmann to be very closely related to rm water species *F. fraudax* Lohm. It seems more that *Fritillaria borealis* is a cosmopolitan species, is known to show many forms, and that the parallel development of forms has occurred in the cold waters of the north and the south.

Doliolidae. There are no purely cold water species except possibly *Doliolina resistibile* (Neumann) in the Antarctic. This species is however regarded by Garstang (1933, p. 213) as a variety of *D. intermedium* Neumann).

Salpidae. There is only one cold water, antarctic-sub-antarctic species *Apsteinia magalhanica* (Apstein); another species *A. racovitzai* (Berc. & Selys-Longchamps) has been described on the basis of a single specimen as slightly different from *A. magalhanica*, but until more specimens are obtained its identity remains doubtful. A form of *Salpa fusiformis* Cuvier also occurs in the Antarctic, viz. *S. fusiformis* form *aspera* (Chamisso).

regarded by some as Arctic. But, while observations made in the eastern Atlantic where the transition zone is wide lead to this conclusion, the distribution on the western side, where the transition from Atlantic to Arctic water is abrupt, seems to indicate that this species may justly be regarded as an Arctic species. The difficulty in demarcating the Arctic zone is clearly shown by an examination of the general oceanic circulation. In the north the main water movement in the deeper layers is southwards; thus representatives of Arctic water are carried in the deeper levels to lower latitudes. In Table I species regarded as purely arctic are those whose distribution on the western side of the north Atlantic indicates that their real home lies in Arctic waters.

In seeking to understand the distribution of species in the cold waters the vertical circulations of the ocean must be considered as well as the horizontal current systems. In Figure 2 is reproduced a diagram showing the type of vertical circulation in the Atlantic ocean (after D e f a n t, 1927). It is evident that in the deeper layers the main body of water is moving in a southerly direction. Thus species evolving outwards into cold water from a warm surface species producing centre will form cold water northern and southern species (Fig. 3). But the ocean circulation is in favour of carrying any northern species that can withstand and reproduce under deep water conditions southwards to the Antarctic, so producing bipolar species. Thus it is likely that any species in the cold northern waters, whether a relic from past ages or one more recently evolved, may become bipolar, but not so antarctic species. In this way the number of pure cold water species is further reduced in the north. In this respect it is interesting that two of the groups with no bipolar species, Tunicata and Ctenophora, are essentially composed of surface living species.

Cold water species may also be evolved as deep sea species from the warm surface layers. Again taking the oceanic circulation into consideration the odds are in favour of polar species evolving from deep water species to the south rather than to the north for in the south existing species will be continually carried into antarctic waters. An examination of the data on Copepods kindly supplied by Mr. F a r r a n rather bears this out. If the genera be divided into surface genera, (in which less than 50 % of the species in a genus can be regarded as deep sea species), and deep sea genera (in which 50 % or over of the species in a genus can be regarded as deep sea species) we find the following result.

	No.	Total No. of species	No. of Arctic and boreal spp.	No. of Antarctic and Subant. spp.	No. of Bipolar spp.
Surface genera	76	525	13	19	5
Deep Sea genera	36	228	3	18	1

The great majority of cold water species b
ging to "deep-sea" genera are found in the anta
Further support is also given by the fact that
are also relatively more bipolar species
among "surface" than "deep-sea" genera.

The actual number of bipolar epiplank
species is small compared with the total numb
species of plankton animals. It seems pro
that their bipolarity can be sufficiently expl
by the conditions of the vertical circulation o
ocean without the necessity for regarding the
hypothetical relics of a past homogeneous

It is worthy of mention that the majori
epiplanktonic bipolar species occur in sub-
waters and are probably able to withstand a
siderable range of temperature.

Space will not allow further discussio
problems raised by an examination of Tab
It is only necessary to call attention to the
that our knowledge of the fauna of the P
and Indian oceans falls far short of that o
Atlantic ocean. The differences and phylog
relations between those species which are pe
to the Atlantic and those peculiar to the P
also appear worthy of study. And certain g
of soft-bodied animals, such as the Ctenop
Siphonophores, and Gymnosomatous Ptero
which are difficult to preserve need special atte
in the future.

The actual contents of Table I appear
in proportion to the labour involved in its pr
tion, but it is surely a noteworthy tribute t
labours of workers in the past that it has
possible to produce such a table at all.

As regards future work S t e u e r (1933
suggested that in the planning for further e
tions attention should especially be paid t
distribution zones in coastal regions and al
the Pacific ocean. There seems also to be
essential difference between the fauna of the w
and eastern halves of the Atlantic worthy of
study; and the examination of the deep-water f
of the different ocean basins needs special atte

For the study of geographical distrib
whether over large or over small areas, att
must also be drawn to the valuable results
to be obtained by the use of the continuous pla
recorder invented by H a r d y (1926).

It has been remarked that the distributi
the coastal forms needs further study. This
us to examine the results of the plankton colle
by the International Council. In no part
world have the coastal waters received g
attention than in the area which comes und
aegis of this Council. The whole area bor
our coasts was examined for a period of
from 1902 to 1908. As a result it was po
to publish the Plankton Resumés in which de
pictures of the distribution of most of our s
have been reproduced. In the final summa

Ostenfeld (1931) subdivided the plankulations of the area covered into a number enient groups according to their distribution. t is possible to pick out species that are presentative of the different divisions there rally considerable overlapping among the of species. Examination of the distribution n the Plankton Resumés shows that there mplete range of animals from those that ely brackish water species to purely oceanic This range may be exemplified as follows): —

h water e. g. *Eurytemora affinis*
and brackish water
e. g. *Acartia bifilosa*
low salinity
e. g. *Oithona nana*

e. g. *Centropages hamatus*
oceanic, existing all the year round under c conditions.
e. g. *Centropages typicus*
oceanic, existing only part of the year in c regions,
e. g. *Aglantha digitalis*

se types also show the major geographical tions outlined above, and overlap in range vise shown here. But whereas many species ver rather a wide area, the boundaries for species coincide with the limits for certain nasses.

the beginning of the International Council nme it was emphasized that "The study of ting organisms had particular worth for the of hydrographical problems". While it vays been fully realised that it should be lly possible to make use of plankton orgaas an aid to the study of water movements, ernational survey did not appear to come p to expectation in this respect. There are reasons to account for this. The identificasome species was not always certain. The ons were not always sufficiently regularly Large nets were not used and therefore the animals were not caught in sufficient s. The results for each group were given cialists to work up and the plankton has not been sufficiently studied as a whole. ation of the report shows that only one or cies in any group are likely to be suitable cators; and it is often the *association* of lifferent species that gives the necessary on. Owing to their very widespread distrithe majority of species are of little value respect unless examined in great detail. cator must be a *practical* indicator.

owe the first idea of the use of plankton rs chiefly to the work of Cleve and villius (1898). Gran (1902, pp. 98—owed that such sweeping generalisations as Cleve made could not hold good, because the composition of the plankton was modified as the conditions in the moving water mass altered, and because it changed with time of year. He also insisted that full use of plankton organisms as indicators could not be made until their life histories and habits were better known. In this latter respect Kramp (1927 and 1930) has ably shown how a thorough knowledge of the biology of hydroids and medusae may be of practical importance in the study of water movements.

There is no doubt that with our increasing knowledge much more use of plankton animals as indicators under certain conditions could be made at the present time. It is therefore worth examining the conclusions and observations of previous workers. Gran (1902, p. 104) has said "the characteristic forms of the regions can be used as indicators, in so far as they are dominant; there will however always be fairly wide boundary regions, where the characteristic forms of both current regions are mixed". "Species may be found outside their regions. When they occur as secondary constituents of the plankton together with indigenous species we can conclude that water from the distribution region of the visitors must occur as a mixture."

The results of the plankton collections of the Belgica expedition to the Greenland Sea were critically examined by Damas and Koefoed (1907) from the point of view of the use of plankton animals as indicators. They conclude that "the use of pelagic organisms as indicators of currents is a local science, based on the knowledge of the special habits of each form, in the region considered". "The same species can in fact be an excellent indicator for the polar current in the north and for the Atlantic current in the south".

They give two examples of circumstances under which the plankton can be employed with certainty as an indicator of currents.

1. An organism which, being totally absent in an ocean basin appears there suddenly and periodically. In the Greenland Sea this case is realised by the species, of southern origin, which the Gulf Stream brings from temperate and even tropical regions.

2. The occurrence of meroplanktonic organisms off shore. *Cyanea capillata* and the medusae born on the continental plateau of the Norwegian coast are good examples. They can be regarded as certain indicators for coastal water; this was also maintained by Gran (1902, p. 105).

Gran (1902, p. 106) has also pointed out that while plankton organisms may be reliable as indicators of surface waters, it is more difficult to make use of them for studying the water movements in the deeper layers owing to their habits of vertical migration.

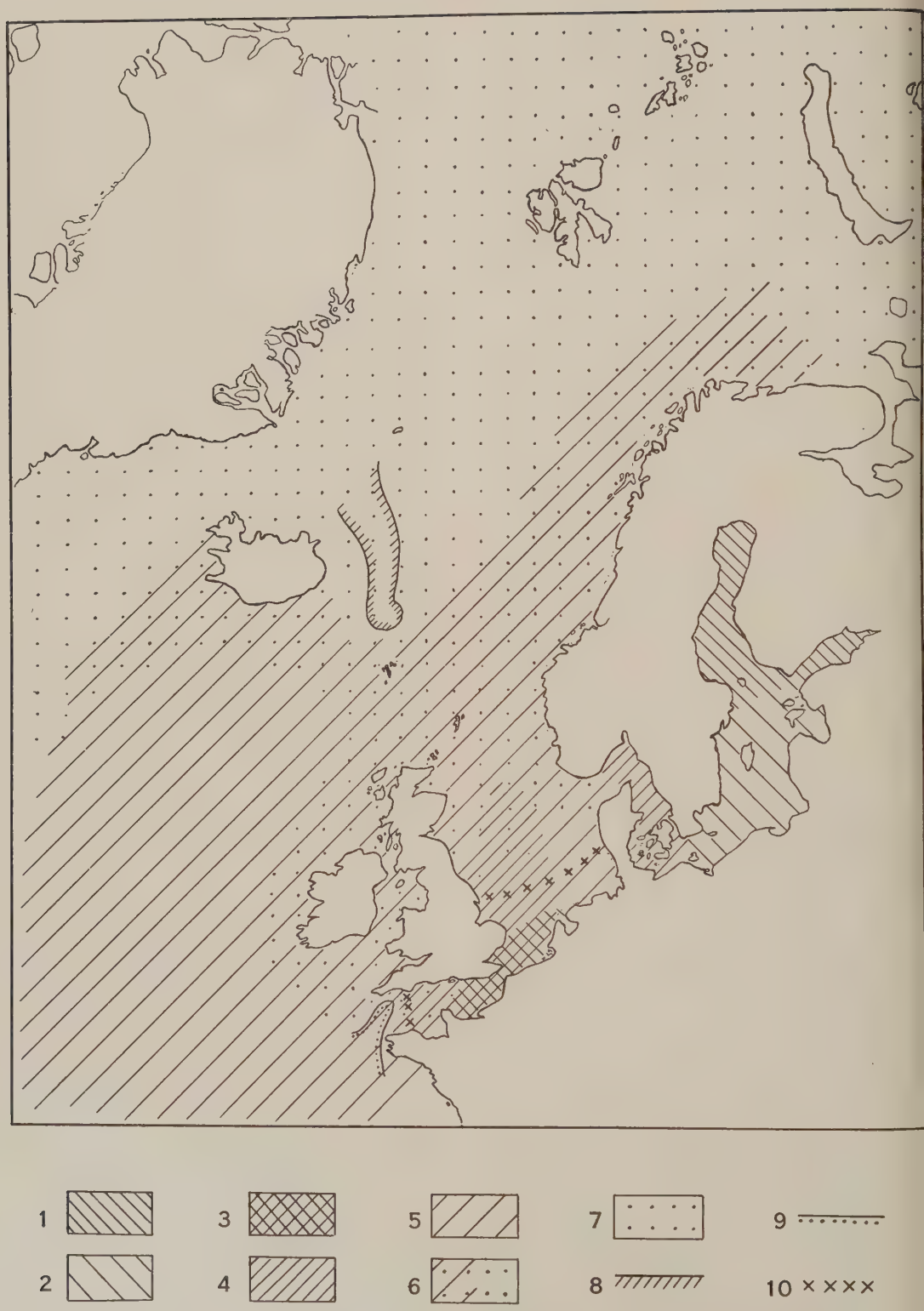


Fig. 4. (as to legend: see the following page).

lankton animals must therefore be used with mination if they are to be employed as ators, and they must be taken in their context. we must be on our guard at times against ng conclusions from the occurrence of a indicator, owing to the possibility that an ism having been brought into the region some previously finds conditions suitable for the lishment of a local race. But the appearance number of indicators together, with different s, must be taken as an indication of influx of (See also Kramp, 1927, p. 231).

urthermore because doubt has been cast upon se of an animal as an indicator in one ty it does not necessarily imply that the same al may not be useful elsewhere.

hus, as Gran (1902, p. 105) has pointed out, *us hyperboreus* must be used with caution an dicator of Arctic water in Norwegian waters, it is indigenous in some Norwegian fjords, n other regions it may well be of value. arly *Clione limacina*, a boreal-arctic species, ot be used *in name* as an indicator of Arctic because it lives successfully in temperate tic waters also. Yet in regions where there possibility of Arctic influence such as the h of the English Channel the species may be as an indicator of Atlantic water. It is mely likely however that with a thorough ledge of its growth and size at maturity in c and Atlantic waters it should be possible iscriminate between Clione of Arctic regions those from Atlantic waters. This is a type of racial investigation so exemplified by the work of the late Prof. Schmidt, and by the studies by Steuer on copepods.

The occurrence of immigrants into an endemic Atlantic plankton community has been dealt with in detail in the Gulf of Maine by Bigelow (1926, pp. 51—69). In Figure 5 is reproduced a chart from his report showing the chief routes followed by planktonic immigrants entering the Gulf at different levels. This chart shows the course of circulation of the water masses as clearly as do hydrographic data. Bigelow says for instance that "The lines of dispersal followed, respectively, by *Sagitta serratodentata*, Eukrohnia, and *S. maxima* within the gulf correspond closely with the dominant drift of water at as many levels — that is, surface, mid, and deepest — as made evident by the physical data afforded by temperature and salinity and drift bottles" (1926, p. 64).

Bigelow stresses the value of knowing to what extent the immigrants are capable of living and reproducing under the new conditions (see Table II). He says (1927, p. 923) "Clearest evidence of the drift within the Gulf is afforded, of course, by such species as are comparatively short lived there and can not reproduce in its low (or high) temperature". Such knowledge would be of great value in judging how recent an influx had been and the age of the water masses.

It is especially valuable to watch for any correlations between the presence or absence of certain plankton animals with that of fish and larger swimming animals. Frost, Lindsay and Thompson (1934) have for instance shown a correlation between the abundance of Squid in Newfoundland waters and that of *Sagitta serratodentata*. This is of clear value for the cod fisheries. In the North Sea Meek (1928) showed that the two species of Sagitta, S. *elegans* and *S. setosa*, were apparently representative of different water masses. The study of the Sagitta populations has been carried a stage further at Plymouth, (Russell, 1935 a), and it has been found that *S. elegans* is an indicator of Atlantic water and *S. setosa* of Channel water. In association with *S. elegans* we find the typical Atlantic community consisting of Aglantha, Cosmetira, Stephanomia, Clione, Meganyctiphanes, and Luidia larvae. These or closely allied species are the indicators that Künne (1934) has given for the south west Dogger Bank swirl. It is thus possible that the two species of Sagitta may prove of great importance as aids to the study of the distribution and movements of water masses in the North Sea. In the Channel the two Sagitta populations appear to sway to and fro past Plymouth according to the strength of flow of Atlantic water into the North Sea from the North. This is in agreement with Carruthers' theory that the Straits of Dover act in buffer relationship between the waters of the North Sea and the

Fig. 4.

bution regions of coastal and oceanic plankton ls in north eastern Atlantic and adjacent waters. Brackish water, *Eurytemora affinis;* region of greatest bundance in August and November (after Scott, late XVIII).

Littoral and brackish water, *Acartia bifilosa;* region f greatest abundance (after Scott, 1911, Pl. XXII).

Neritic — low salinity, *Oithona nana;* region of reatest abundance (after Farran, 1911, Pl. XV.).

Neritic, *Centropages hamatus;* region of greatest bundance (after Scott, 1911, Pl. XVIII.).

Atlantic species, *Acartia clausi*, area of distribution after Jespersen, 1934, p. 123.).

Arctic — boreal species, *Calanus finmarchicus*, showing outherly limit of abundant occurrence (after Farran, 1911, p. 83).

Arctic species e. g. *Limacina helicina.*

Area in which the Arctic species *Calanus hyperboreus* vas recorded as abundant; this is in the East Iceland Polar Current (after Farran, 1911, p. 89 and Pl. XI, nd Damas, 1905, Pl. I.).

Limit of area within which the warm water species *Euchaeta hebes* occurred on at least 20 % of the ccasions on which observations were made (after Farran, 1911, Pl. XIV.).

Southern limit in North Sea and Eastern limit in Channel of Arctic-boreal species *Clione limacina* (after Paulsen, 1910, p. 53).

Table II.

List of Plankton Animal Indicators.

Arctic water.

1. A high temperature is fatal and they soon perish. (1)[1])

Ctenophore	Mertensia ovum.	Gulf of Maine (1)
Medusae	Ptychogena lactea	„ „ „ (1)
	Sarsia princeps	Labrador Current (20)
Pteropod	Limacina helicina	Gulf of Maine (1)
		Barents Sea and North of Iceland
Tunicate	Oikopleura vanhöffeni	Gulf of Maine (1)
		Newfoundland (2)

2. Able to survive for a considerable period and even reproduce to some extent. (1)

Copepods	Calanus hyperboreus	East Iceland Polar Current (4, 5,
		Gulf of Maine (1)
	Metridia longa	East Iceland Polar Current (4)
		Gulf of Maine (1)
Pteropod	Clione limacina	„ „ „ (1)

Mixed arctic and atlantic water.

Species unable to breed in high (or low) temperatures (1)

1. Surface layers.

Chaetognath	Sagitta serratodentata	Gulf of Maine (1, 19)
Euphausian	Nematoscelis megalops	„ „ „ (1)

2. Intermediate layers (say below 50 m.)

Chaetognath	Eukrohnia hamata	„ „ „ (1, 19)
Siphonophore	Diphyes arctica	„ „ „ (1)

3. Deepest layers (150 m. or deeper)

Chaetognath	Sagitta maxima	„ „ „ (1, 19)

Entering north western North Sea

Euphausian	Thysanoessa longicaudata	North Sea (6)

In Newfoundland waters (2) a relation has been shown between the abundance of *Sagitta serratodentata* and that of the squid *Illex illecebrosus* during the years studied, 1931, 1932 and 1933.

Atlantic water.

Water entering north western North Sea round north coast of Scotland.

Euphausians	Meganyctyphanes norvegica	North Sea (6)
	Thysanoessa inermis (in winter only)	„ „ (6)

In regions away from influence of Arctic water.

Medusae	Aglantha digitalis var. rosea	S. W. Dogger swirl (7)
		Channel (8)
	Cosmetira megalota	S. W. Dogger swirl (7)
	Cosmetira pilosella (in spring and summer only)	Channel (8)
Siphonophore	Agalma elegans	S. W. Dogger swirl (7)
	Stephanomia bijuga	Channel (8)
Chaetognath	Sagitta elegans (should probably also prove of value in southern N. Sea)	Channel (8)
Euphausians	Meganyctiphanes norvegica	Channel (8)
	Thysanoessa inermis	Channel (8)
	Nyctiphanes couchi	S. W. Dogger swirl (7)
Pteropod	Clione limacina	Channel (8)
		S. W. Dogger swirl (7)
Echinoderm	Luidia sarsi young	Channel (8)
		S. W. Dogger swirl (7)
Tunicate	Oikopleura labradoriensis	S. W. Dogger swirl (7)
		Newfoundland (typical of mixed perate water) (2)

[1]) Numbers in brackets are those of the references at the foot of the table.

Warm atlantic water.

es	Salpa fusiformis	North Sea (9, 10, 11), Channel (8), Gulf of Maine (1)
	Salpa democratica	Ditto
	Cyclosalpa bakeri	North Sea
	Doliolum nationalis	North Sea, Channel (8)
	Doliolum gegenbauri	North Sea (12), Channel (8)

There are no boreal or arctic salps or doliolids; the presence of any species in these groups erefore be regarded as an indication of water from warmer latitudes.

	Liriope exigua	Channel (8)
phore	Muggiaea atlantica	Channel (13)
	Muggiaea kochi	Channel (8)
	Physophora borealis	North Sea and Norwegian coast (17, 18)
	Cupulita sarsi	" " " " " (17, 18)
	Arachnactis larvae	" " " " " (17)
ia	Lepas fascicularis	" " " " " (17)
la	Anomalocera patersoni	Norwegian Sea (18)

Coastal water.

	Cyanea capillata	Norwegian Ocean (14, 17)
	Cyanea lamarcki	North Sea (17)
	Sarsia princeps	Spitzbergen (17)
	Sarsia flammea	"
	Catablema eurystoma	"
	Bougainvillea superciliaris	"

meroplanktonic species with a fixed bottom stage in its life history is indicative of coastal nd its distance off shore is dependant on its length of life in the planktonic stage (14, 18).

nath	Sagitta setosa	Channel (8) (probably also North Sea)

coastal water of the Channel (8) and southern North Sea (7) is also distinguishable from At- vater by its poverty in animal plankton.

in species are given by K r a m p (15) as likely to be carried into the southern North Sea *via* nnel.

	Turritopsis nutricula, Amphinema dinema, Slabberia halterata, Gossea corynetes, Octorchis gegenbauri, Cosmetira pilosella.
ian	Nyctiphanes couchi.

ese Cosmetira and perhaps Nyctiphanes will have been carried in Atlantic water.

Eastern and Southern Kattegat.

(16) gives as visitors introduced from the north:—

Bougainvillea britannica, Laodicea undulata, Staurophora mertensii, Melicertum octocostatum, Mitrocoma polydiademata, and Cosmetira pilosella.

References.

gelow (1926); 2, Frost, Lindsay and Thompson (1934); 3, Paulsen (1910); 4, Farran (1911); s (1905); 6, Kramp (1913); 7, Künne (1934); 8, Russell (1935); 9, Schmidt (1909); 10, Bow- 23); 11, Apstein (1911); 12, Lucas (1933); 13, Gough (1905); 14. Damas and Koefoed (1907); mp (1930); 16, Kramp (1927); 17, Damas (1909); 18, Gran (1902); 19, Huntsman (1919); ıp (1926).

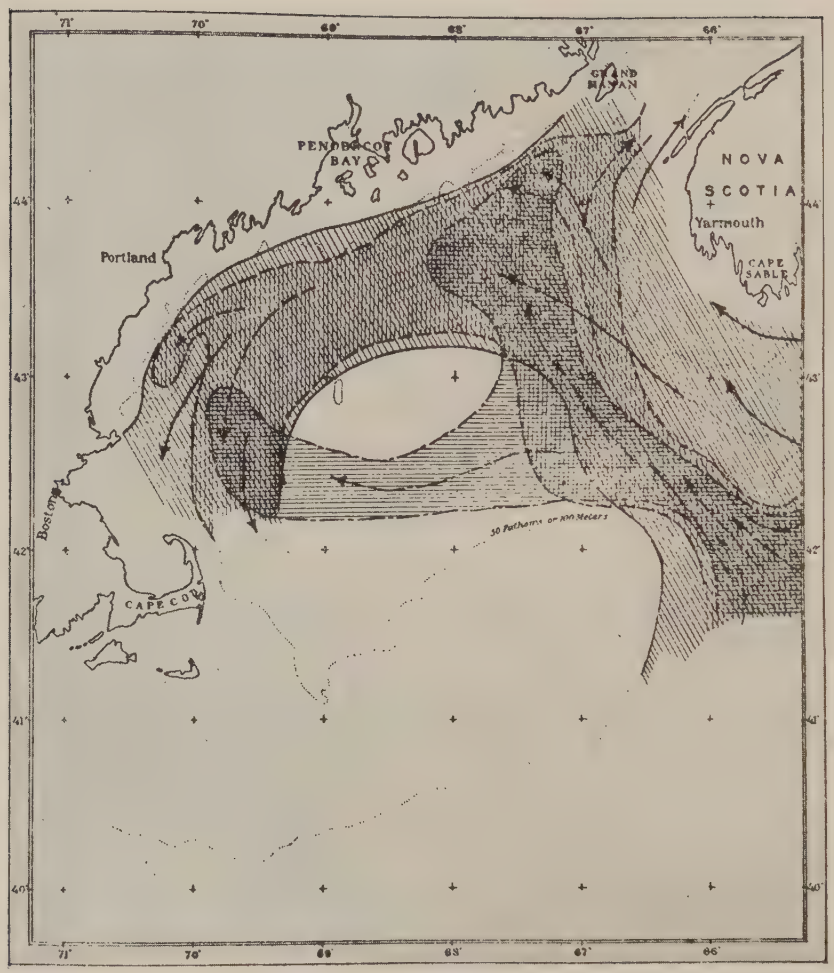


Fig. 5.
Chief routes followed by planktonic immigrants entering the Gulf of Maine at different levels. ▨, immigrants at surface; ▥, immigrants at intermediate levels; ▤, immigrants at the deepest leve
(After Bigelow 1926, p. 65, Fig. 33).

Channel. Thus a correlation appears to be shown between the occurrence of *S. setosa* off Plymouth and the presence of concentrations of Rhizosolenia in the southern North Sea studied by Savage and Hardy (1935) (Russell, 1935). When the Atlantic flow from the North is strong *Rhizosolenia styliformis* and phosphate rich water is carried into the southern North Sea and *S. elegans* is pushed westward in the Channel so that *S. setosa* appears off Plymouth.

From the knowledge now available I have drawn up in Table II a list of certain plankton animals and the water masses of which they can be regarded as indicators in certain regions. In this list I have included only those animals that are sufficiently large and easily identified to be practical indicators. At this stage the list is tentative but it should be the aim of future to produce a similar table in greater detail

Especial attention should be paid to of the life histories of some of the large boreal species such as *Sagitta elegans* and *limacina*. It is characteristic of species v wide type of distribution that they sho considerable differences in the size to wh grow and at which they mature both fro to place and season to season. Our know the life histories of such species should brought together and comparisons made different water masses. It will prob possible then to distinguish between differ of growth and maturity for the differen A species such as *Calanus finmarchicus* is known to show similar characteristic va

Fig. 6.
en area with the surface temperatures for March to April 1922. The darkened areas show the centres where have been made during winter time for both species investigated, and to which the spawning of *Calanus hyper-* limited. The area shaded is the cold area into which most numbers of *Calanus hyperboreus*, females and larval carried after spawning time,and where the main spawning of *Calanus finmarchicus* takes place (after S ø m m e, 1934, p. 9. Fig. 1).

e are to fix upon indicators they must be indicators and therefore species that do re microscopic examination for identifica- measurement. Owing to the use of small in the International Investigations the ecies were not caught in sufficient numbers heir utility.

the point of view of fishery investigations e realised that plankton indicators are of importance. If correlations can be shown onsistently for a number of years it should ble to predict certain conditions in the Large plankton indicators can be seen at and the delay necessary for the detailed of water samples is avoided.

ould seem that these larger plankton hould prove of much greater value as aids graphy than the nannoplankton organisms. ng the distribution of water masses it is daries along which the masses mix that o have demarcated. With their rapid rate duction nannoplankton organisms will ncrease in numbers in water which has seeded with individuals carried either in ne surface layers or in small eddies at ate depths. A false impression would thus ced; whereas by the change in numbers ger animals it should be possible to gain a of the quantities of water of different at have been intermingled. But as has been stressed by G r a n and K r a m p it is first essential that the life-histories and habits of the animals should be thoroughly known.

The different stages in the life histories of many of the commoner plankton animals of north European waters have now been described from the morphological point of view. For the life histories of the copepods we are indebted especially to such workers as O b e r g, G r o b b e n and W i t h, while L e b o u r has gone a long way towards describing many of the planktonic larval stages of bottom animals. But we still know very little of the habits and biology of the different developmental stages in the sea. It is a remarkable fact that the actual yearly sequence in the succession of broods of our commonest plankton animal, *Calanus finmarchicus*, was only demonstrated in detail for the first time in 1933 by N i c h o l l s at Millport. The early work of D a m a s and K o e f o e d on the copepods in northern waters has now been carried considerably further by the work of R u u d, J e s p e r s e n, and S ø m m e. The life story of *Calanus hyperboreus* in Norwegian waters has been made especially clear by S ø m m e. The length of life and seasonal occurrence of many Hydromedusae have been worked out by K r a m p in Danish waters. The growth and breeding of *Sagitta elegans* and *Sagitta setosa* are now known at Plymouth (R u s s e l l, 1932—33). These are a few examples (see Fig. 9); but still the number of species that

have received such detailed attention remains surprisingly few. This is an aspect of zooplankton research that needs to be especially developed, for advance in other directions is still likely to be prevented by lack of this necessary knowledge. An understanding of the biology of individual species may throw quite unexpected light on obscure problems. For instance Sømme (1934) has shown how the differences between the horizontal distribution of *Calanus finmarchicus* and *Calanus hyperboreus* in offshore Norwegian waters are the results of slightly different habits of spawning and in the time of their vertical migration after the winter months. After migrating from the deep layers the species are carried away in the surface waters "from the winter localities out over the coastal banks" (Fig. 6).

But if the biology of plankton animals is to be fully understood, it is necessary also to know their relations with their environment. We must know their food supply, their enemies, and the nature of the balance that exists in the community in which they live; and also their relations with the physical and chemical factors of their environment. It is only by gaining this knowledge that we can study the question of production of life in the sea, which may be intimately bound up in one of the greatest problems of marine biology, namely the causes of the fluctuations in the populations of our food fishes. When we consider the relations amongst the animals themselves we find that we have at our command a considerable knowledge that should be put to greater use in the future. Largely through the researches of Lebour (1918—1923) we have a very detailed knowledge of the food of most of our commoner plankton animals and young fish. The work especially of Bullen (1908 and 1912), Jespersen (1928), Savage (1931), and Hardy (1924) has shown to what extent the different plankton animals are preyed upon by fishes. But the interactions of the plankton animals upon one another have been little explored. Lohmann (1908) by his great work in Kiel Bay gave a picture of the total plankton production throughout a year under the conditions there existing. Since then the work has not been repeated in other regions. This is perhaps largely because we have been awaiting the development of method. It is now possible to measure plant production much more rapidly by chemical methods, and possibly we shall soon be able to say the same for the measurement of total zooplankton (see Cooper, 1934). But the necessity for a study of the interactions between species still remains, and this was not dealt with by Lohmann because life histories were insufficiently known. We have also been held back by the lack of methods for comparing the numbers of plants and animals from known volumes of water. There has been great want of uniformity in the types of nets used in the past. Hensen, when he intr quantitative methods into plankton research, a net on lines which he calculated woul greatest efficiency. In his examination fishing capacities of many different ty plankton nets Künne (1929 and 1933) has that Hensen's type of net is still th efficient. With nets of coarse mesh for the of the larger plankton animals the filtration are likely to be small if the plankton is n abundant. But with the finest silk required t the small copepod nauplii the errors due tration will be large. The filtration coeffic the net varies widely according to the am plankton present and may be anything up high as 6 or over (Kǫkubo and Ta 1931).

We have therefore always hesitated to catches with fine meshed plankton nets as of exact treatment. But recently a net ha designed by Harvey (1934) which gi actual measure of the volume of water t passed through the net. The meter can be us silk of any required mesh, and with simul hauls it should be possible to use it f calibration of large coarse meshed nets. As of the introduction of this net it is now to examine the relations between the phytop crop *retained by the net* and the animals upon it. But the work can be carried further. The effects produced by the rav predatory plankton animals on the plant population should be observed. Such ani medusae, ctenophores, and chaetognaths, are voracious, and unusual abundance of any will lead to a considerable decrease in t available for post-larval fishes as well as destruction of the fish themselves. (Ru 1935 b.). The balance of life would be soo by a sudden increase in the numbers predators and the increasing demand for they grew in size.

As Hardy (1924, p. 33) has said "It by having some concrete representation normal marine community that one can att predict the effect which an abnormal inc one or other particular form — — — m in the balance of the whole". He produce structive diagram reproduced here (Fig. 7 gives a good illustration of the lines on wh aspect of research should develop.

When we see a sample of plankton caug a given body of water at a given time realise that this does not represent a sta dition. We are looking at a cross sectio moment in one place of a continuous phe moving both in time and in space. The s the result of past history and posse potentiality for future history. It will con population of producer plants, of plant co

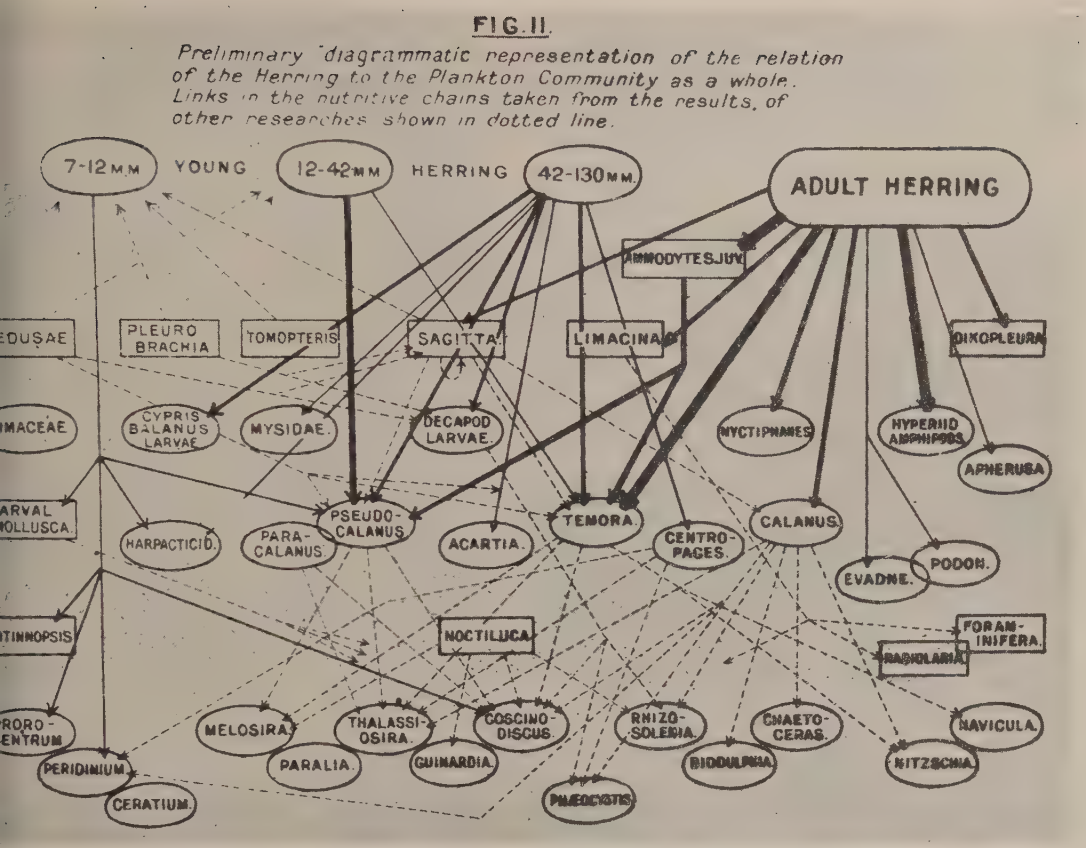


Fig. 7.

nary representation of the relation of the herring to the plankton community as a whole (after Hardy, 1924, Fig. 11).

predatory carnivores. The population will up of the balance of plants composed of nal stock plus the sum of the increase by tion and the decrease by death and con-; and similarly the balance of consumers from their interactions with the carnivores. w (1931, p. 131) has rightly pointed out yet we know little of the interrelationships rent species or groups of animals in the nd the obvious fact that some prey on ut we may be certain" he says "that in ses interrelationships of less obvious sorts links in animal economy".

lthough we know something of the type of voured by most plankton animals, it is to visualise the course of events between e samples because little is known about the *ood requirements* of the animals. The f Pütter that plankton animals must arge proportion of their food supply from organic substances in the water has re-en critically reviewed by Krogh (1931). udes that "there is no convincing evidence" that dissolved substances are taken up in significant amounts. Indeed it is likely that all metazoan plankton animals depend mainly for their food supply on particulate living or detrital matter and on colloidal material (see Gellis and Clarke, 1935). Recent observations by Marshall, Orr, and Nicholls (1935) on the respiration of *Calanus finmarchicus* have confirmed the earlier observation by Ostenfeld and Knudsen (1913, p. 424) on *Calanus hyperboreus* which indicated that the figures put forward by Pütter were too high. Pütter estimated that in general Calanus required as food 39 % of its body weight daily in summer. Marshall, Nicholls and Orr found that for stage V Calanus this figure lay between 6.2 and 7.6 % in summer. In a recent survey of the phytoplankton and zooplankton collected with Harvey's measuring net at Plymouth it was concluded that the summer zooplankton per cubic metre required daily 120,000 diatoms of average size. The daily production of this quantity of vegetation could reasonably be expected. It is a quarter of the average diatom population caught

in the measuring net during this period, a net which undoubtedly lets many very small plant organisms pass through it. This is in agreement with Lohmann's conclusions for Kiel Bay that during the spring and summer months the producer plankton was in excess. The problem of the food requirements of plankton animals is open to attack in two ways. Direct observation may be made in the laboratory on the amount and type of organisms that any species will eat. Work of this nature has already been started at Woods Hole by Clarke and Gellis (1935) and also in Professor A. C. Hardy's laboratory at Hull. Such work indeed as the notable research on the rearing of planktonic crustacean and molluscan larvae by Lebour (1924—34) and polychaete larvae by Wilson (1928—33) at Plymouth was originally made possible by the work by Allen and Nelson (1910) on the culture of marine diatoms, which are now used so largely as food in rearing experiments. On the other hand observations may be made on the rate of respiration under controlled conditions in the laboratory. In order that this second method can prove applicable to conditions in the sea it will be necessary to know the weights and chemical composition of the different plankton organisms. Such work is already started and was foreshadowed many years ago by Brandt (1898). Observations on the weight and chemical composition of a number of plankton crustacea have already been made, notably by Orr, Wimpenny, and Klem (1929). The vitamin content of plankton oils is also being investigated (Drummond and Gunther, 1934). Studies on the weights of copepods by Bogorov (1932—34) see the inauguration of an extensive programme on the part of Russian biologists to assess the total quantity of life in the sea at any time from quantitative counts on the basis of a knowledge of the weights and composition of the different species. At first sight it would appear that the task of weighing and analysing all the plankton animals is likely to be excessive. Indeed it is not so great as it appears, the number of species are limited and once the necessary data have been obtained for any one species the results are final and need but to be tabulated for future reference. These results could no doubt be further simplified by classifying the species into size categories somewhat after the style of Hentschel's (1934) recent suggestion. Admittedly the work is not exciting to the zoologist. But the various attempts to obtain the necessary information such as the calculation of displacement by volume of models by Lohmann (1908), and the recent suggestions by Gunther (1934) and Hentschel (1934) emphasize the need for agreement on some form of standard data.

It will be suitable at this stage to draw attention to the need for more experimental work on the physiology of plankton animals. Such knowledge is most necessary to explain some of the typ behaviour that we now know to be show animals in the sea. Perhaps in no way doe plankton animal give indications of chang physiological state better than in its habi changing vertical distribution. The migr towards the surface at night is our first indic of direct reaction to some external or int stimulus. We now know that not only are these nightly wanderings, but that the animal exhibits changes throughout its life history ac ing to its age. At times also the animals be apparently irresponsive to external changes different times of year we find the same sp behaving in a different manner, pointin physiological differences between different br The external factors affecting the behaviour o animals as shown by vertical distribution, na salinity, temperature, oxygen content, and hydr ion concentration have been investigated in the It is only recently, however, largely throug pioneer work of Poole and Atkins, tha have obtained the means of determining variation in intensity and composition of that important factor, light. In the vertical distrib of the same species in regions many latitudes there is no doubt that the main controlling f is that of temperature. If an animal is ada to live within a certain range of temperature lethal effects of temperatures above this range the temperatures limiting successful reprodu must naturally overweigh the possible disadvan that may arise owing to abnormal light condit But the changes shown from day to day and se to season in any one place are undoub manifestations of physiological change whic fects the animal in its response to light condit Until the post war period our knowledge o vertical distribution of plankton animals largely confined to the gross differences show the results of collecting from widely spaced d in ocean waters, and the conditions in co waters had not been systematically studied. the general facts of daily and seasonal migra were fully recognised. In recent years the stu this problem has been carried out on a finer in shallow waters (Russell 1925—1934), similar work in deep ocean waters is now done at Woods Hole (Leavitt, 1935). result of the accumulated knowledge and ide past workers and of my own researches at Plym it became possible to draw hypothetical diag showing the distribution to be expected at time of day of animals requiring optimum intensity conditions and migrating under the mulus of light (Russell, 1927). It ca realized that by varying the scales of lengt day, strength of light, depth of optimum, t parency of the water, and swimming speeds o animals any number of such diagrams can be d

ıe different kinds of movements. Support in of this theory has come from field work. haviour of female *Calanus finmarchicus* as by N i c h o l l s (1933) fits the hypothetical n to a remarkable degree. The study is now being carried further by C l a r k e (1933 and 1934 a) at Woods Hole with simultaneous observations of distribution and light conditions (Fig. 8.).

But it is no longer agreement with theory that

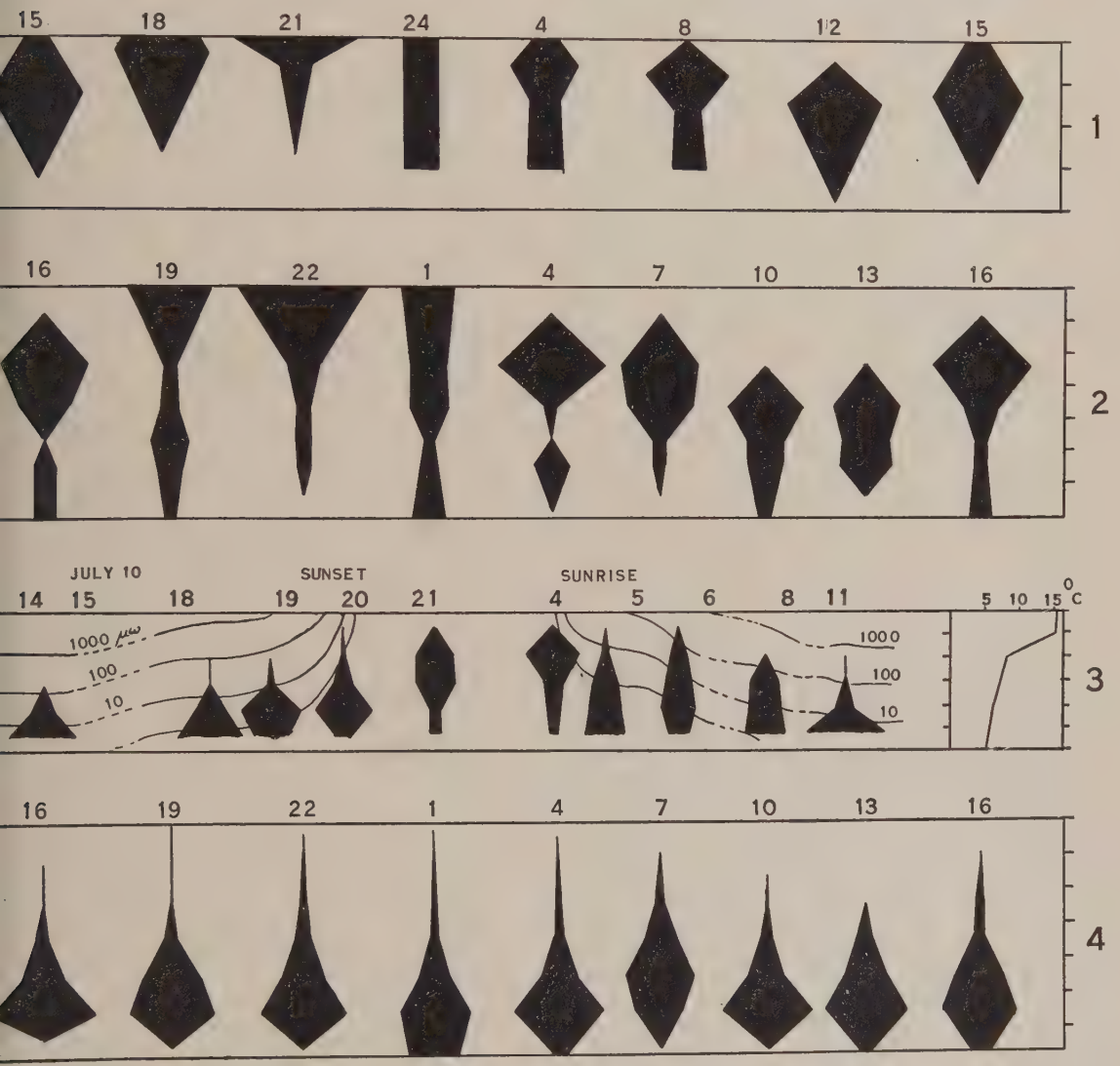


Fig. 8.

Distribution of Plankton Animals.

thetical vertical distributions at different times in wenty-four hours to illustrate the behaviour of a ation of a species such as *Calanus finmarchicus* diurnal movements, (after R u s s e l l, 1927, p. 237, 4).

am showing vertical distribution of female *Calanus rchicus* at 3-hourly intervals during 24 hours on ry 25th—26th, 1932; sunset 4.27 p. m.: sunrise . m. (after N i c h o l l s, 1933, p. 150, Fig. 4).

al migration of adult females of *Metridia lucens* in the Gulf of Maine, July, 1932. The changes in light intensity are indicated by the lines representing the depth at which 1000, 100 microwatts etc. occurred (one microwatt may be taken as approximately equal to three metre-candles). The temperature curve at the right shows that migration right to the surface at night was prevented by the thermocline (after C l a r k e, 1933, p. 426, Fig. 5).

4. Diagram showing vertical distribution of Stage V *Calanus finmarchicus* at 3-hourly intervals on Jan. 25th—26th, 1932 (after N i c h o l l s, 1933, p. 148, Fig. 3).

we wish to observe. It is by seeking for disagreements that advances are made. For it is where behaviour is contrary to this theory that we shall find the clues to the differences in the physiological state of the animals themselves.

It has been mentioned previously that at times the animals appear to be irresponsive to light changes. A very good example of this has been shown for the fifth copepodid stage of *Calanus finmarchicus* (Nicholls, 1933). The possible significance of this state is worth consideration. The gonads of a copepod do not usually mature until the moult into the adult stage is completed. The fifth copepodid stage is the final stage of immaturity and immediately on developing into the adult stage the gonads start to ripen. After moulting into the adult stage or possibly even immediately before this moult the copepod becomes once more responsive to light conditions and exhibits typical migrational movements. After the successive production of the spring and summer broods, the offspring surviving from the final brood have to pass the winter months. It is in this irresponsive fifth stage that Calanus exists for the long period from August until the following February, when the final moult into the adult takes place. These animals thus have to survive a period when there may be a prolonged deficiency of their diatom food. Orr (1934; Marshall, Nicholls, Orr, 1934) has shown that the Stage V individuals of *Calanus finmarchicus* are loaded with fat in the late summer. They must therefore live to a certain extent on these reserves. But they will obviously benefit if they can reduce their metabolic activity to a minimum. A daily wandering up and down under the stimulus of changing light conditions will be unnecessary waste of energy when no supply of food is being produced in the surface layers. Light itself may have an effect upon the rate of metabolism, although the results of Marshall, Nicholls and Orr (1935) seem to show that it is doubtful whether this effect will be felt much below a depth of five metres. One of the most obvious ways for a plankton animal to reduce its expenditure of energy is thus by seeking the deeper layers and becoming irresponsive to the stimulus of changing light conditions. In this respect the observation made by Sømme (1934, p. 81) that copepods kept in the dark are dull and sluggish compared with those exposed to subdued light seems very significant.

Evidence is not wanting that many plankton animals seek deeper layers in winter. It was long ago shown by Gran (1902) and Nordgaard that *Calanus finmarchicus* might be found in the winter in the deep water layers at the bottom of the Norwegian fjords. This habit has been examined more fully by Sømme for *Calanus finmarchicus* and *C. hyperboreus*, and it has been shown that a considerable stock of both these species survives the winter in these deep near the coast undergoing migrations towar surfac e layers after the winter (see Fi Sømme also remarks that near Tromsø species do not undertake extensive daily v migrations during the winter time. Beebe in his dives in the bathysphere below the zone has remarked that in the regions of per night the plankton and pelagic animals di appear to show those phototropic responses search light so characteristic of animals of th face fauna. Possibly these deep sea organisn permanently irresponsive; but if this were would be difficult to understand the functi the light emitting organs; it may have bee his search light was too powerful, or th animals are only stimulated by rays from pho escent light.

The habit of some plankton animals to se deeper levels in winter is possibly quite co able with that of hibernation of animals on Indeed this habit may be largely responsi deciding to what degree an animal shall be oc Unless an animal can find the required de the winter months it will not survive. Thus v draw the distinction between an animal that certain coastal regions find sufficiently deep such as *Calanus finmarchicus*, which dies dc a meagre band of survivors during winter in low waters; one such as *Calanus hyperboreus* requires greater depths but may still be fou the deepest fjords; and an animal which is pc even more oceanic such as Aglantha the las mer brood of which may not be able to survi winter in shallow water. Kramp (1927, p in discussing the occurrence of Aglantha in th Sea says: "I think myself it is rather the depth of this water which renders it less su as a permanent habitat for Aglantha". Such o animals when brought once more into waters after their vertical migration in the months of the year can reproduce and thrive coastal conditions so long as the summer last during the hibernation period they must se depths or perish.

It must not be overlooked also that at certain plankton animals may live actually in the bottom (Clarke, 1934, b; Rus 1932—33). In Figure 9 are shown sequences of life histories.

Enough has been said to show how a full ledge of the biology of the different spec plankton animals is essential to explai differences in their abundance and distributio time to time. In this respect it is not suffic base conclusions on results obtained in a locality. It has been found that the same spe animal appears to show a different behavi one region from that which it shews in a For instance in the waters off Plymouth the

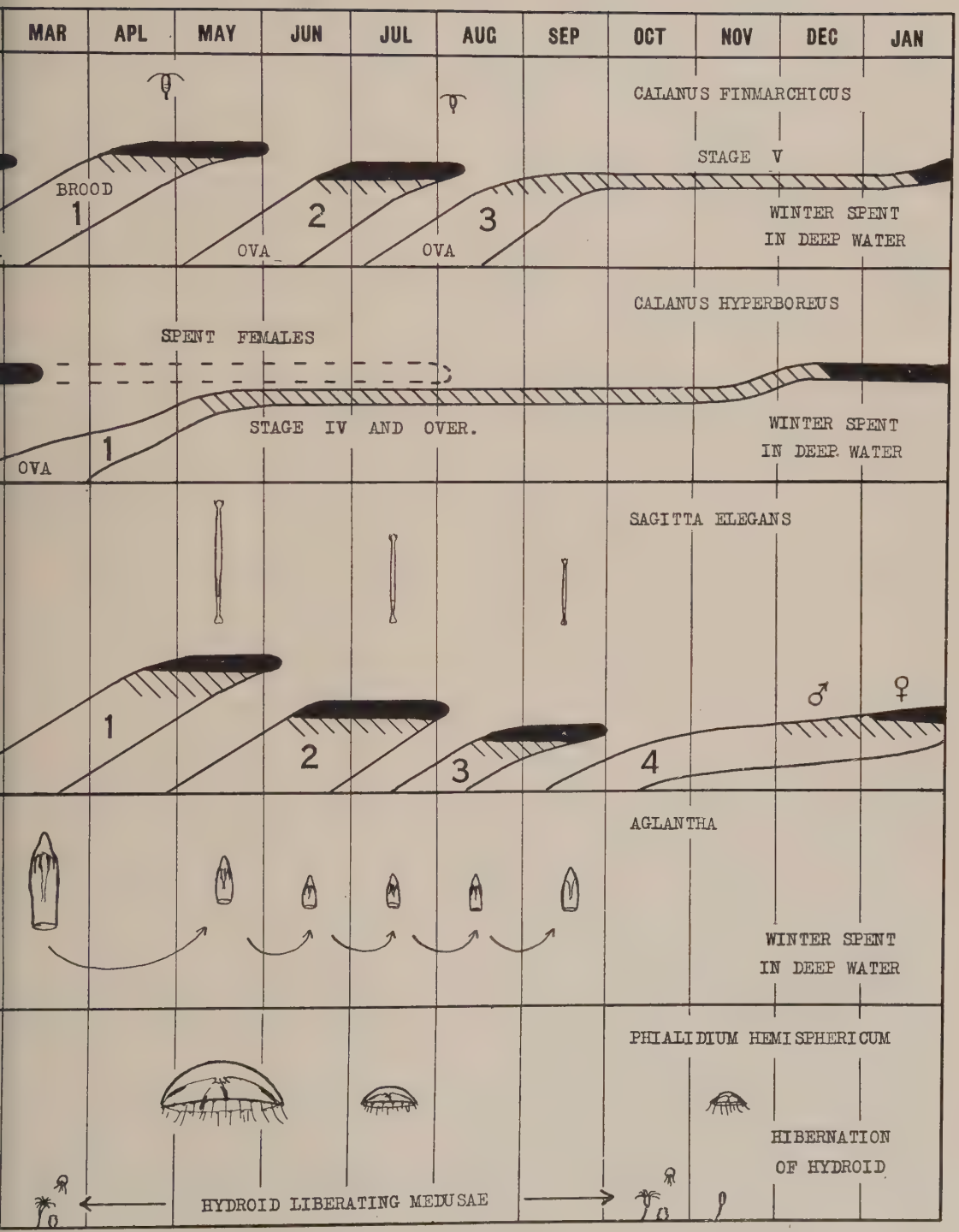


Fig. 9 (as to legend: see following page).

of *Calanus finmarchicus* maturing in July lives very much nearer the surface in the daytime than do the preceding broods. Whereas in the Clyde Sea area (Marshall, Nicholls and Orr, 1934) and in the North Sea (Gardiner, 1933) the brood maturing in May appears to live nearest the surface. This seems to point to some essential difference in the animals themselves.

The seasonal behaviour and production of successive broods of plankton animals needs to be studied in polar and tropical regions, and also in the deep waters of the ocean. The stimulus of external temperature conditions has been largely regarded as responsible for deciding the time of onset of maturity and spawning. It is however difficult to understand how this factor can decide the delay in the development of the sexual shown in the last summer brood of many pl animals — that is the brood which surviv winter. It seems almost that we must rega successive annual production of broods as c able with the annual breeding cycle of an that may live for a number of years. That i a prolonged period of reproduction a per recuperation is necessary. In temperate wat recuperative period falls apparently for species during the winter months. May it that some essential factor has been remove the water during the summer which becomes able again only after a period of time or is p lacking in the diminishing food supply?

Fig. 9.

Diagrammatic representation of the life histories of *Calanus finmarchicus, Calanus hyperboreus, Sagitta elegans,* Aglantha and *Phialidium hemisphaericum.* These are examples of species in which several broods are produced during the year, and of a species which produces only one brood a year. *Sagitta elegans* and *Calanus finmarchicus* are Arctic-boreal species. The diagrams represent their life histories under boreal conditions. It is probable that in Arctic waters they produce only one brood a year as the arctic species *C. hyperboreus.* In the diagrams the period of full maturity is indicated in black and the state immediately preceding maturity is shown by shading. This latter period corresponds to copepodid Stage V in the copepods and the ripening of the male sexual organs in Sagitta.

The height of the diagram for each brood give an indication of the size to which the adults grow, and above each brood is given a life size representation of the animal itself. The noteworthy feature is the prolonged existence in the final immature state during the winter and the retirement to deep water.

A. Succession of Broods of *Calanus finmarchicus.* This is based on the results of Marshall, Nicholls and Orr (1933—35) at Loch Striven. There are three main breeding periods in the year covering the periods February—March, April — May — June, July — August. Spawning does not take place with the same intensity throughout a whole period, but in any one year it is likely to be most intense in one month, e. g. February, May and July. Individuals of the first brood, developing during the coldest period of the year grow to the largest size and weight. Thereafter they decrease in size as the temperature rises. The first born in any brood are generally the largest for that brood.

In 1933 the last brood which was hatched mainly in July had established the autumn-winter stock of Stage V by August 14th. These persist mostly as Stage V and moult into adults in January and February.

The work of Farran (1927), Russell, and Bogorov (1934, a) shows that this sequence is essentially the same in the waters south of Ireland and in the western end of English Channel.

Maximum length.

Females.	Median length of cephalo-thorax.		Dry Weight.
Loch Striven (Marshall-Orr)	2.76 mm.	(24.iv.33)	0.28 mg.
Plymouth (Russell)	2.82[1])	(19.v.26)	
(Bogorov)	2.89[1])	(22.v.30)	0.252[2])

Minimum length.

Loch Striven	2.26	(28.viii.33)	0.1
Plymouth	2.46[1])	(26.vii.26)[3])	
	2.26[1])	(16.x.30)	0.1

The copepods grow larger in cold waters warm, e. g. Bogorov gives for Barents Sea:

Females.	Average total length.	Ten
69°30′ N — 75° N.	3.22 mm.	
75° N. — 77° N.	3.78	
North of 77° N.	4.57	—

Adler and Jespersen (1920) and Jesp (1934) have given the following variations in l cephalo thorax

Eastern North Sea ..... ca. 1.9—2.7
West Greenland Waters ..... 2.4—4.5

[1]) Originally given as total length, convert cephalo-thorax length by factor 0.8 (see Clar p.00).

[2]) Formalin preserved material; there will have be slight loss in weight.

[3]) No observations later than Sept. 22nd.

The percentage of fat is highest in Stage V: the autumn winter stock in September had 6 % than the corresponding individuals in the January to March.

Sømme has shown that in Norwegian wa majority of *C. finmarchicus* spend the winter greater than 200—300 metres. After the winter an annual vertical migration completed about th of March; development of the eggs takes place vertical migration.

B. Seasonal cycle of *Calanus hyperboreus.* This on Sømme's (1934) results for Norwegian wa

There is only one brood in the year. takes place in February and March. The developmental stages are passed through by Ap which specimens earlier than copepodid Stage not found. A few females start to ripen in N but the majority do not do so until mid-Decem January. The males are found only between I and the beginning of May, mostly in Janu February. After spawning in February and Ma of the spent females may survive until the August.

winter is passed in deep layers mostly below 0 m. and deeper than *C. finmarchicus*. The vertical migration after the winter months is ed by the middle of April; the development of s takes place *before* this vertical migration. there is only one brood there is no seasonal ism in size.

copepods grow larger in cold waters than in e. g. Bogorov gives for the Barents Sea:—

	Total Average Length.	Wet weight.	Temperature.
N.—75° N.	6.0 mm.	4.0 mg.	4.7° C.
-77° N.	7.1	8.6	1.08
f 77° N.	8.0	13.4	—0.50

lar type of life history is shown by *Calanus* (Campbell, 1934) in the Strait of Georgia on cific Coast of North America.

ion of broods of *Sagitta elegans*. This is based results of Russell (1932—33) at Plymouth. re are probably four main breeding periods the year, i. e. February, May, June—July, and ber. Individuals of the first brood developing at lest time of the year grow into the largest adults. ter they decrease in size in the successive broods temperature rises.

roximate average length of adults:—

May (1930)	19.5—20 mm.
une—July	13 —14.5
September	10 —10.5
February (1931)	12 —12.5

The offspring arising from the September spawning do not start to mature until December when the male sexual organs start to ripen. The female sexual organs do not start to ripen until January. There is an indication that there is a descent to deeper water during the winter.

D. Probable succession of broods of *Aglantha digitalis* var. *rosea*. This is based on results of Russell at Plymouth (unpublished). Development is direct, without a hydroid generation. Large individuals 12 to 18 mm. in height, which have survived the winter living probably in deep water, spawn in February and March. The adults of this first brood grow to about 6 or 7 mm. in height. During the summer months successive broods of small individuals, 5 or 6 mm. in height, are produced. There is an indication at Plymouth that there are at least three such broods.. The offspring from the last spawning in August or September grow into the larger sized individuals which survive the winter and spawn the following February.

E. Biology of the Medusa *Phialidium hemisphaericum* in the plankton. Based on results of Russell (unpublished) and Orton (1920) at Plymouth.

The medusae are produced from the hydroid *Clytia johnstoni*. The hydroid starts producing medusae in numbers in March. The medusae liberated early in the year grow to a large size, individuals being found in May up to 19 mm. in diameter with as many as 32 tentacles. During the summer the successive adults are smaller and smaller until in September they have a diameter of only 5 or 6 mm. with usually about 16 tentacles. In November the hydroid polyps die down and the hydroid "hibernates" until the following March.

(Compare also, Kramp, 1927).

References.

G. and Jespersen, P. 1920. Variations ières chez quelques Copepodes planctoniques Medd. Komm. Havund., Ser. Plankton, Vol. 2.

. J. and Nelson, E. W. 1910. On the Ar- Culture of Marine Plankton Organisms. Journ. iol. Assoc., N. S., Vol. VIII, No. 5, pp. 421—474.

, C. 1906. Die Salpen. Deutsche Südpolar- 1901—1903. Bd. IX, Zool. Bd. I., Heft III, pp. 03.

Tunicata. Résumé des observations sur le Plank- s Mers explorées par le Conseil pendant les 1902—1908. Cons. Perm. Internat. Explor. Mer. rim. Pt. II. pp. 150—162.

r, H. 1929. Die Polychaeten der Weddellsee. ev. d. ges. Hydrobiol. Hydrog., Bd. 22, pp. 2.

lius, Carl W. S. 1898. Vergleichende Thier- hische Untersuchungen über die Plankton-Fauna ageraks in den Jahren 1893—1897. Kungl. Sven- tenskaps-Akad. Handl. Bd. 30. No. 3, pp 1—426.

William. 1934. Half Mile Down. Harcourt, & Co., New York.

, Henry B. 1911. The Siphonophorae. Rep. s. Expedition to the eastern tropical Pacific ... U. S. Fish Commission Steamer "Albatross". Mus. Comp. Zool. Cambridge, Mass. XXXVIII, pp. 173—402.

Bigelow, Henry B. 1926. Plankton of the Offshore Waters of the Gulf of Maine. Bull. Bur. Fish. Washington. Vol. XL. 1924 Pt. II. Doc. No. 968. pp. 1—509.

— 1927. Physical Oceanography of the Gulf of Maine. Bull. Bur. Fish. Washington. Vol. XL. 1924. Pt. II, Doc. No. 969, pp. 511—1027.

— 1931. Oceanography. Its Scope, Problems and Economic Importance. Chapman & Hall, Ltd. London. pp. 1—263.

— 1931. Siphonophorae from the Arcturus Oceanographic Expedition. Zoologica. Sci. Contrib. New York Zool. Soc. VIII, No. 11, pp. 525—592.

Bogorov, B. G. 1932. Materials on the Biology of the Copepods of the Barents and the White Seas. Bull. State Oceanogr. Inst. U. S. S. R. No. 4, pp. 1—16.

— 1933. Modifications in the Biomass of *Calanus finmarchicus* in accordance with its age. Bull. State Oceanogr. Instit. No. 8, pp. 1—16.

— 1934 a. Seasonal changes in Biomass of *Calanus finmarchicus* in the Plymouth area in 1930. Journ. Mar. Biol. Assoc., N. S., Vol. XIX, No. 2, pp. 585—612.

— 1934 b. On the term "biomass of a plankton organism". Bull. All-Union Scient. Res. Inst. Mar. Fish. Oceanogr. No. 2, p. 28.

Bogorov, B. G. & Preobrajenskaya, E. 1934. On the weight characteristics of the plankton organisms of the Barents Sea. II. Copepoda. Bull. All-Union Scient. Res. Inst. Mar. Fish. Oceanogr. Nr. 2, pp. 1—25.

Bonnevie, Kr. 1913. Pteropoda from the "Michael Sars" North Atlantic Deep-Sea Expedition 1910. Rep. Sci. Res. "Michael Sars" N. Atlantic Deep-Sea Exped. 1910. Vol. III. Pt. 1. pp. 1—69 (Reprinted 1933).

Bowman, A. 1923. The Biological Interchange between the Atlantic and the North Sea. Rep. Brit. Assoc. Adv. Sci., London, 1922, p. 367.

Brandt, K. 1898. Beiträge zur Kenntniss der chemischen Zusammensetzung des Planktons. Wiss. Meeresunt., Abt. Kiel., u. f. 3, pp. 45—90.

Brinkmann, August. 1917. Die Pelagischen Nemertinen. Bergens Mus. Skrift. Bd. III. No. 1, pp. 1—180.

Bullen, G. E. 1908. Plankton studies in relation to the western Mackerel fishery. Journ. Mar. Biol. Assoc., N. S., Vol. VIII No. 3, pp. 269—302.

— 1912. Some notes upon the feeding habits of mackerel and certain Clupeoids in the English Channel. Journ. Mar. Biol. Assoc., N. S., Vol. IX, No. 3, pp. 394—403.

Campbell, Mildred H. 1934. The Life history and post-embryonic development of the copepods, *Calanus tonsus* Brady and *Euchaeta japonica* Marukawa. Journ. Biol. Board Canada, Vol. I, No. 1, pp. 1—65.

Clarke, George L. 1933. Diurnal Migration of Plankton in the Gulf of Maine and its correlation with changes in submarine irradiation. Biol. Bull. Vol. LXV, No. 3. pp. 402—436.

— 1934 a. Further Observations on the Diurnal Migration of Copepods in the Gulf of Maine. Biol. Bull. Vol. LXVII, No. 3, pp. 432—455.

— 1934 b. The Diurnal Migration of Copepods in St. Georges Harbor, Bermuda. Biol. Bull. Vol. LXVII, No. 3, pp. 456—460.

Clarke, G. L. and Gellis, S. S. 1935. The Nutrition of Copepods in Relation to the Food-Cycle of the Sea. Biol. Bull., Vol. LXVIII, No. 2, pp. 231—246.

Collin, G., Drummond, J. C., Hilditch, T. P., and Gunther, E. R. 1934. Observations on the Fatty Constituents of Marine Plankton. II. General character of the Plankton oils. Journ. Exper. Biol., Vol. XI, No. 2, pp. 198—202.

Cooper, L. H. N. 1934. The Determination of Phosporus and Nitrogen in Plankton. Journ. Mar. Biol. Assoc., N. S., Vol. XIX, No. 2. pp. 755—759.

Damas, D. 1905. Notes Biologiques sur les Copépodes de la Mer Norvégienne. Cons. Perm. Int. Explor. Mer, Publ. Circ. No. 22, pp. 1—23.

— 1909. Contribution à la biologie des Gadides. Cons. Perm. Int. Explor. Mer., Rapp. Proc. Verb. Vol. X., No. 3, pp. 1—277.

Damas, D. et Koefoed, E. 1907. Le Plankton de la Mer du Grönland. Croisière Océanographique accomplie à bord de la Belgica dans la mer du Grönland 1905, pp. 347—453.

Defant, A. 1927. Über die wissenschaftlichen Aufgaben und Ergebnisse der Expedition. Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor". Zeits. Ges. Erdkunde zu Berlin. Nr. 7/8, pp. 359—369.

Drummond, J. C. and Gunther, E. R. 1934. Observations on the Fatty Constituents of Marine Plankton. III. The Vitamin A and D Content of Oils derived from Plankton. Journ. Exper. Biol. Vol. XI, No. 2, pp. 203—209.

Farran, G. P. 1911. Copepoda. Résumé des observations sur le Plankton des Mers explorées par le Conseil pendant les Années 1902—1908. Cons. Perm. Internat. Explor. Mer., Bull. Trim. Pt. II. pp. 81—105.

Farran, G. P. 1927. The reproduction of *Cala marchicus* off the south coast of Ireland. C Explor. Mer. Journ. du Cons. Vol. II, No. 2, pp.

Frost, N., Lindsay, S. T. and Thompson, Plankton. Annual Report Year 1933. Rep. N land Fish. Res. Comm. Vol. II, No. 2. pp. 47—

Gardiner, A. C. 1933. Vertical Distribution in *finmarchicus*. Journ. Mar. Biol. Assoc., N. XVIII, No. 2, pp. 575—610.

Garstang, Walter. 1933. Report on the Part I. — Doliolida. Brit. Antarct. ("Terra Exped., 1910. Nat. Hist. Rep. Zool., Vol. IV pp. 195—251.

Gellis, S. S. and Clarke, G. L. 1935. Organi in dissolved and in colloidal form as food for *magna*. Physiol. Zool., Vol. VIII, No. 2, pp.

Gough, Lewis Henry. 1905. On the Dis and the Migrations of *Muggiaea atlantica*, Cun in the English Channel, the Irish Sea, and South and West Coasts of Ireland, in 1904. Con Int. Explor. Mer., Publ. Circ. No. 29, pp. 1—13

Gran, H. H. 1902. Das Plankton des Norwegische meeres von biologischen und hydrographischen punkten behandelt. Rep. Norweg. Fish. Mar Vol. II. No. 5, pp. 1—217.

Gunther, E. R. 1934. Observations on the Fa stituents of Marine Plankton. I. Biology of the Journ. Exper. Biol., Vol. XI, No. 2, pp. 173—1

Hardy, A. C. 1924. The Herring in Relatio Animate Environment. Part I. The Food and Habits of the Herring with Special Reference East Coast of England. Min. Agric. Fish., Fish Ser. II. Vol. VI. No. 3, pp. 1—53.

— 1926. A New Method of plankton research. Vol. 118, p. 630.

Harvey, H. W. 1934. Measurement of Phyto Population. Journ. Mar. Biol. Assoc., N. S., V No. 2, pp. 761—773.

Hensen, Victor. 1895. Methodik der Untersu Ergeb. d. Plankton-Expedition d. Humboldt- Bd. I, B. pp. 1—200.

Hentschel, Ernst. 1934. Eine Methode zu suchung von Copepodenbevölkerungen. Cons. P Explor. Mer., Rapp. Proc. Verb., Vol. LXX 93—97.

Huntsman, A. G. 1919. Some Quantitative and tive Plankton studies of the Eastern Canadian Canadian Fish. Exped., 1914—1915, pp. 405—4

Jespersen, P. 1928. Investigations on the Foo herring in Danish Waters. Medd. Komm. Havu Plankton. Vol. II.

— 1934. The Godthaab Expedition 1928. Copepod Grønland Komm. Vid. Undersøgels. Grønland, Nr. 10, pp. 1—166.

Kokubo, S. and Tamara, I. 1931. A Quanti vestigation of the Plankton of Aomori Bay, a comparatively by Pump and Net Collection. Iôhoku Imper. Univ. 4th. Ser. Biol. Vol VI pp. 491—531.

Kramp, P. L. 1913. Schizopoda. Résumé des obs sur le Plankton des Mers explorées par le pendant les Années 1902—1908. Cons. Perm. Explor. Mer., Bull. Trim. Pt. III. pp. 539—55

— 1926. Medusae. Part. II. Anthomedusae. Danis Expedition, Vol. V, Pt. 10, pp. 1—102.

?. L. 1927. The Hydromedusae of the Danish Kgl. Danske Vidensk. Selsk. Skrift., Naturvid. fd. 8. R. XII. 1. pp. 1—290.

ydromedusae collected in the south-western part orth Sea and in the Eastern part of the Channel –1914. Mém. Mus. Roy. d'Hist. Natur. Belgique. o. 45, pp. 1—55.

August. 1931. Dissolved substance as food tic organisms. Biol. Reviews, Vol. VI, No. 4, –442.

Cl. 1929. Vergleich der Fangfähigkeit ver- er Modelle von Plankton-Netzen. Cons. Perm. olor. Mer., Rapp. Proc. Verb. Vol. LIX, pp.

Weitere Untersuchungen zum Vergleich der Fang- t verschiedener Modelle von vertikal fischenden n-Netzen. Cons. Perm. Int. Explor. Mer., Rapp. erb., Vol. LXXXIII, pp. 1—35.

ericht über die Teilnahme an einer Fischerei- hrt der "Weser" zu Untersuchungen über die ung der Heringslarven in der südlichen Nordsee n Kanaleingang. 5. Die Verbreitung des Gross- s. Deutsch. Wiss. Komm. f. Meeresforsch. N. F. Heft 3.

Benjamin B. 1935. A quantitative study of tical Distribution of the larger zooplankton in ater. Biol. Bull. Vol. LXVIII, No. 1, pp.).

M. V. 1919—1921. Various papers on the food g fish, in Journ. Mar. Biol. Assoc., N. S., .

923. The Food of Plankton organisms. Journ. ol. Assoc., N. S., Vols. XII and XIII.

934. Various papers on the Development of a and Mollusca, in Journ. Mar. Biol. Assoc., ols. XIII—XIX, and Proc. Zool. Soc. 1928—35.

bertine D., and Van Riemsdijk, Thea. he Siphonophora of the "Siboga" Expedition. Expeditie, IX, pp. 1—130.

n, H. 1905. Die Appendicularien des arktischen arktischen Gebiets, ihre Beziehungen zueinander den Arten des Gebiets der warmen Ströme. hrb. Suppl. VIII, pp. 353—382.

ntersuchungen zur Feststellung des vollständigen des Meeres an Plankton. Wiss. Meeresunter. d. X. Abt. Kiel. pp. 131—370.

eiträge zur Planktonbevölkerung der Weddellsee er Ergebnissen der Deutschen Antarktischen on 1911—1912. II. Die Appendicularien-Be- g der Weddellsee. Int. Rev. d. g. Hydrobiol. ., Bd. 20, Heft 1/2, pp. 13—72.

Die Appendicularien der Deutschen Tiefsee- on. Wiss. Ergebn. "Valdivia" 1898—1899, Bd. . 1—158.

n, H. and Bückmann, Ad., 1926. Die cularien. Deutsche Südpolar-Exped. 1901—1903, III, Zool. X. pp. 65—231.

. E. 1933. Occurrence of *Dolioletta gegenbauri*) in the North Sea. Nature, Vol. 132, p. 858.

osh, N. A. 1934. Distribution of the Macro- in the Atlantic Sector of the Antarctic. y Reports, Vol. IX, pp. 65—160.

Marshall, S. M., Nicholls, A. G. and Orr, A. P. 1934. On the Biology of *Calanus finmarchicus*. V. Seasonal Distribution, Size, Weight and Chemical Composition in Loch Striven in 1933, and their relation to the Phytoplankton. Journ. Mar. Biol. Assoc., N. S., Vol. XIX. No. 2. pp. 793—827.

Marshall, S. M., Nicholls, A. G. and Orr, A. P. 1935. On the Biology of *Calanus finmarchicus*. Part VI. Oxygen Consumption in Relation to Environmental Conditions. Journ. Mar. Biol. Assoc., N. S., Vol. XX. No. 1, pp. 1—27.

Massy, Anne L. 1920. Mollusca. Part III. Eupteropoda (Pteropoda Thecosomata) and Pterota (Pteropoda Gymnosomata). British Antarctic ("Terra Nova") Exped. 1910: Nat. Hist. Rep. Zool. Vol. II. No. 9, pp. 203—231.

Meek, Alexander. 1928. On *Sagitta elegans* and *Sagitta setosa* from the Northumbrian Plankton, with a Note on a Trematode Parasite. Proc. Zool. Soc. London. pp. 743—776.

Meisenheimer, Johannes. 1905. Pteropoda. Wiss. Ergeb. Deutsch. Tiefsee-Exped. "Valdivia" 1898—1899. Bd. IX. Lief. 1, pp. 1—314.

Moser, F. 1909. Die Ctenophoren. Deutsche Südpolar-Exped. 1901—1903, Bd. XI, Zool. III. Heft. II, 1, pp. 117—192.

Moser, F. 1925. Die Siphonophoren der Deutschen Südpolar-Expedition, 1901—1903, zugleich eine neue Darstellung der ontogenetischen und phylogenetischen Entwickelung dieser Klasse. Deutsche Südpolar-Expedit. Bd. XVII, Zoologie, Bd. IX, pp. 1—541.

Neumann, Günther. 1913. Die Pyrosomen und Dalioliden der Deutschen Südpolar-Expedition 1901—1903. Deutsch. Südpol.-Exped. Bd. XIV. Zool. Bd. VI. Heft 1, pp. 1—34.

Nicholls, A. G. 1933. On the Biology of *Calanus finmarchicus*. I. Reproduction and Seasonal Distribution in the Clyde Sea-Area during 1932. Journ. Mar. Biol. Assoc., N. S., Vol. XIX, No. 1, pp. 83—109.

— 1933. On the Biology of *Calanus finmarchicus*. III. Vertical Distribution and Diurnal Migration in the Clyde Sea-Area. Journ. Mar. Biol. Assoc., N. S., Vol. XIX. No. 1, pp. 139—164.

Orr, A. P. 1934. On the Biology of *Calanus finmarchicus*. Part IV. Seasonal Changes in the Weight and Chemical Composition in Loch Fyne. Journ. Mar. Biol. Assoc., N. S., Vol. XIX. No. 2. pp. 613—632.

Orton, J. H. 1920. Sea-Temperature, Breeding and Distribution in Marine Animals. Journ. Mar. Biol. Assoc., N. S., Vol. XII. No. 2. pp. 339—366.

Ostenfeld, Carl Hansen. 1913. De Danske Farvandes Plankton i Aarene 1898—1901. Phytoplankton og Protozoer. (avec un résumé en français). Kgl. Danske Vidensk. Selsk. Skrift. 7. Række, Naturvid. Math. Afd. 2, pp. 117—478.

— 1931. Résumé des observations sur le Plankton des Mers explorées par le Conseil pendant les Années 1902—1908. Cons. Perm. Int. Explor. Mer., Bull. Trim. Pt. IV, pp. 601—672.

Oye, Paul van. 1918. Untersuchungen über die Chaetognathen des Javameeres. Contributions Scientifiques de Buitenzorg's Lands Plantentuin, Fac. IV. pp. 1—61.

Paulsen, Ove. 1910. Pteropoda. Résumé des observations sur le Plankton des Mers explorées par le Conseil pendant les Années 1902—1908. Cons. Perm. Intern. Explor. Mer., Bull. Trim. Pt. I, pp. 52—59.

Pruvot-Fol, Alice. 1924. Étude de quelques Gymnosomes Méditerranéens des pêches d l'"Orvet" en 1921 et 1922. Arch. Zool. Expér. Génér., Tome 62, pp. 345—400.

Rammner, Walter. 1933. Die Cladoceren der "Meteor"-Expedition. Wiss. Erg. Deutsch. Atlant. Exped. "Meteor" 1925—1927. Bd. XII Biol. Sond. Lief. 2. pp. 111—121.

Ritter-Zahony, R. von. 1911. Revision der Chätognathen. Deutsche Südpolar-Exped. 1901—1903, Bd. XIII, Zool. V, Heft. I, pp. 1—71.

Russell, F. S. 1925—1934. The Vertical Distribution of Marine Macroplankton. Parts I—XII. Journ. Mar. Biol. Assoc., N. S., Vol. XIII—XIX.

— 1927. The Vertical Distribution of Plankton in the Sea. Biol. Reviews. Vol. II, No. 3, pp. 213—262.

— 1932—33. On the Biology of Sagitta. Parts I—IV. Journ. Mar. Biol. Assoc., Vol. XVIII.

Russell, F. S. 1935 a. On the Value of Certain Plankton Animals as Indicators of Water Movements in the English Channel and North Sea. Journ. Mar. Biol. Assoc., N. S., Vol. XX, No. 2.

Russell, F. S. 1935 b. The Seasonal Abundance and Distribution of the Pelagic Young of Teleostean Fishes caught in the Ring-Trawl in Offshore Waters in the Plymouth Area. Part II. Journ. Mar. Biol. Assoc. N. S. Vol. XX, No. 2.

Ruud, Johan T. 1929. On the biology of copepods off Möre, 1925—1927. Cons. Perm. Int. Explor. Mer., Rapp. Proc. Verb., Vol. LVI. pp. 1—84.

Savage, R. E. 1931. The Relation between the Feeding of the Herring off the East Coast of England and the Plankton of the surrounding waters. Min. Agric. Fish., Fish. Invest. Ser. II. Vol. XII. No. 3, pp. 1—88.

Savage, R. E. and Hardy, A. C. 1935. Phytoplankton and the Herring. Part I. 1921 to 1932. Min. Agric. Fish., Fish. Invest. Ser. II. Vol. XIV. No. 2. 1934, pp. 1—73.

Schmidt, J. 1909. The Distribution of the Pela and the Spawning Regions of the Gadoids in th Atlantic from Iceland to Spain. Cons. Per Explor. Mer., Rapp. Proc. Verb., Vol. X, No 1—229.

Scott, Thos. 1911. Copepoda. Résumé des obse sur le Plankton des Mers explorées par le pendant les Années 1902—1908. Cons. Perm. Explor. Mer., Bull. Trim. Pt. II. pp. 106—149.

Sømme, Jacob D. 1934. Animal Plankton Norwegian Coast Waters and the open Sea. duction of *Calanus finmarchicus* (Gunner) and *hyperboreus* (Krøyer) in the Lofoten Area Norweg. Fish. Mar. Invest. Vol. IV. No. 9, pp.

Steuer, Adolf. 1933. Zur planmässigen Erfo der geographischen Verbreitung des Haliplankt sonders der Copepoden. Zoogeographica, Bd. I. pp. 269—302.

Stiasny, G. 1934. Das Bipolaritätsproblem. Néerlandaises Zool., Tome I, pp. 35—53.

Tesch, J. J. 1904. The Thecosometa and Gymnoso the Siboga-Expedition. Siboga Expeditie, LII. p

— 1906. Die Heteropoden der Siboga-Expedition. Expeditie, LI. pp. 1—110.

Wheeler, J. F. G. 1934. Nemerteans from th Atlantic and Southern Oceans. Discovery Repo IX, pp. 215—294.

Wilson, Douglas P. 1928—33. Various pa the Development of Polychaetes, in Journ. M Assoc. N. S., Vols. XV—XVIII.

— 1932. On the Mitraria larva of *Owenia fusiform* Chiaje. Phil. Trans. Roy. Soc. London. Ser. B. pp. 231—334.

Wimpenny, R. S. 1929. Preliminary Observa the Fat-Content of the Plankton on the English grounds in the North Sea. Min. Agric. Fisheri Invest., Ser. 2 Vol. XI, No. 5, pp. 1—23.

FURTHER INVESTIGATIONS ON THE PHOTOSYNTHESIS OF PHYTO-PLANKTON BY CONSTANT ILLUMINATION.

BY

H. HÖGLUND AND S. LANDBERG.

DURING the spring of 1934 we carried out together with Hans Pettersson some experiments on submarine daylight and the photosynthesis of phytoplankton. Our results were that the "compensation light-intensity" (i. e. the intensity of submarine daylight requisite for producing equilibrium between photosynthesis and respiration) could be ascertained to approximately 400 lux. (see H. Pettersson, H. Höglund and S. Landberg: "Submarine daylight and the Photosynthesis of Phytoplankton", in Meddelanden för Göteborgs Högskolas Oceanografiska Institution No. 10, Göteborg 1934).

Unfortunately the natural conditions during the experiments were not ideal owing to the abnormally meagre diatom spring increase in the Gullmar Fjord. Our experimental cultures contained proportionally too much zooplankton, which increased the oxygen consumption by respiration in the flasks. Thus the value of the compensation intensity (400 lux) which we found is no doubt somewhat too high.

Hoping that the spring of 1935 would afford better and more normal conditions with a rich diatom growth we planned a continued and more extensive investigation on the same basis and with the same technical arrangements as the spring before. Our expectations were however baffled, for instead of better diatom growth in the Gullmar fjord during this year it was found to be weaker than during last year. The number of diatoms in the fjord which was controlled twice a we January to May, never exceeded 200,000 c litre. The diatom growth in the open sea westcoast of Sweden being also little pro we had no opportunity of control. As th natural conditions for the experiments w forth-coming we were bound to confine t investigations to a recapitulation and a veri of those which we carried out last year.

We have worked with the same technical ments as in 1934 described in the above m paper. The manipulations of keeping the meter-deflection constant caused by the current from the Lange-cell have been simplified by combining an electrical moto winch drum for the wire at the end of wh experimental flasks were suspended. Takin giving out more or less wire on the drum light decreased or increased was execu pressing two different buttons by means o the motor was started or coupled free.

As in the previous experiments we add amount of net plankton which increased number in the flasks to nearly 1 mill. p Several series of trials were made and two are exemplified in tables I and II. As th show *we also this year found the "comp light-intensity" to be nearly 400 lux.* T position of the plankton used during thi experiments as is seen from table III diffe what from last year's.

Table I.

n. Illumination at the upper set of flasks ant at about 425 lux, at the lower set of about 375 lux. During the first hour of ment the illumination was very variable f fleecy clouds, thereafter the sky was bright sunshine. Depth of the upper set at start, (10h 0m) 20 metres, at finish, 11.5 metres. Distance between upper set of flasks, 1.38 metres.
on of experiment: 7 hours.
er of Diatom cells per litre: 913,500 (see e III).

n content in cm³. at N. T. P. per litre:

start	"Black" flasks	At finish, after 7 hours: Upper set of flasks	Lower set of flasks	Flasks, kept constant 8 metres below the surface
5.67	5.62	5.66	5.66	5.95
5.67	5.62	5.68	5.68	5.98
5.69	5.66	5.71	5.68	5.98
5.68	5.63	5.68	5.67	5.97
e:	— 0.05	± 0.00	— 0.01	+ 0.29

Table II.

n. Illumination at the upper set of flasks ant at about 425 lux, at the lower set of about 375 lux. Sky slightly overcast. he upper set of flasks, at start, (10h 30m) at finish, (18h 30m) 3 metres. Distance pper and lower set of flasks, 1.38 metres.
on of experiment: 8 hours.
f Diatom cells per litre: 1,123,500 (see e III).

n content in cm³. at N. T. P. per litre:

start	"Black" flasks	At finish, after 8 hours: Upper set of flasks	Lower set of flasks	Flasks, kept constant 4 metres below the surface
3.66	3.59	3.65	3.62	3.93
3.64	3.58	3.67	3.63	—
3.67	3.62	3.68	3.67	3.98
3.66	3.60	3.67	3.64	3.96
e:	— 0.06	+ 0.01	— 0.02	+ 0.30

Table III.

The total number of Diatoms and other organisms in the seawater samples, used during the experiments, *after the addition of net plankton*, determined by means of Utermöhl's sedimentation method with inverted microscop.

	12/4 1935 cells/litre 2 cc analyzed	15/4 1935 cells/litre 2 cc analyzed
Skeletonema costatum	7,000	—
Thalassiosira sp.	1,000	—
Leptocylindrus danicus	12,000	2,000
Rhizosolenia alata	3,500	12,500
Chaetoceros borealis	98,000	85,000
„ *brevis*	13,000	—
„ *compressus*	58,000	54,000
„ *constrictus*	114,000	198,000
„ *curvisetus*	37,000	60,000
„ *danicus*	1,000	—
„ *debilis*	—	7,000
„ *decipiens*	51,000	11,000
„ *densus*	47,000	199,000
„ *diadema*	150,000	124,000
„ *didymus*	3,000	—
„ *laciniosus*	17,000	14,000
„ *radicans*	196,000	226,000
„ *spp.*	99,000	127,000
Thalassiothrix longissima	1,000	—
„ *nitzschioides*	—	2,000
Licmophora lyngbyei	1,000	—
Navicula sp.	4,000	2,000
Diatoms total	913,500	1,123,500
Flagellatae	1,000	—
Dinophysis acuta	1,000	—
Peridinium spp.	5,000	1,000
Ceratium tripos	1,000	6,000
„ *longipes*	7,000	10,000
„ *intermedium*	—	1,000
Gymnodinium sp.	1,000	1,000
Total number of autotrophic cells	929,500	1,142,500
	Specimens/ litre 25 cc/analysed	Specimens/ litre 25 cc/analysed
Favella denticulata	1,080	640
Ptychocylis urnula	520	200
Tintinnopsis sp. (T. beroidea?)	80	360
Leprotintinnus pellucidus	40	—
Strombidium conicum	120	80
„ *strobilus*	40	—
Lohmaniella oviformis	480	160
Synchaeta sp.	880	400
Naupliae	520	440
Copepods	40	200
Fritillaria borealis	—	120
Total number of heterotrophic organisms	3,800	2,600

THE CONTINUOUS PLANKTON RECORDER: A NEW METHOD OF SURVEY

BY

A. C. HARDY, M. A.
PROFESSOR OF ZOOLOGY AND OCEANOGRAPHY,
UNIVERSITY COLLEGE, HULL.

A brief account of the method together with examples of some of the results obtained in collaboration with

G. T. D. HENDERSON, B. Sc., Ph. D.,
C. E. LUCAS, B. Sc. and
J. H. FRASER, M. Sc.,

members of the research staff, Department of Oceanography, University College, Hull.

ON being invited to give a preliminary account of the experiments we are making from Hull in the charting of the North Sea plankton, I accepted with some diffidence, because we are only just reaching a stage in our survey when it is possible to consider correlations and make comparisons between one year and another. I did so because I felt that if the methods and a few examples of the results were discussed at the present stage, the work would benefit most by my inviting the criticism of members of the International Council.

Whilst the present survey has been in progress for just three years, experiments in the method began in 1925 on the first of the present series of expeditions to the Antarctic under the Discovery Investigations. I had been impressed by the sometimes remarkable patchiness of the plankton distribution in the North Sea. By using tow-nets at stations not very close together one must at times obtain a very inadequate impression of the true plankton distribution. It seemed desirable to construct a machine, which could be towed at any required depth below the surface, and, by continually sampling the plankton mile by mile as the ship proceeded on her course, would enable one to measure the size, density and frequency of patches, and compare the irregularity of distribution in different areas. Further, by correlating the varying populations of different species one could make an uninterrupted line of ecological observation across the sea.

The first machine (Hardy 1926), whilst presenting many difficulties and undergoing considerable changes, successfully recorded the variations in the plankton for over 4,000 miles of sea, and showed that the method was practicable.

It now seemed possible to apply the method to a wide and repeated survey of the sea using commercial ships, and to this end a new machine was designed embodying the improvements gained from former failures and reduced to the smallest size consistent with efficiency (Fig. 1). A full description of this machine will be published shortly. It is torpedo-shaped and provided with a system of planes which make it dive and swim horizontally at a constant depth for a given length of towi (for speeds of 6 to 13 knots). A shock a placed at the towing head eliminates vibrati water to be sampled enters by a small unob opening at the front, passes down a tun cross-section of which increases greatly i until it reaches the filtering gauze and ther the back. The filtering gauze, silk boltin of 60 meshes to the inch, is a long l arranged to wind off one roller and pass the water tunnel, immediately after which it by another gauze banding winding off a roller and together they pass between two rollers and on into a tank of formalin. In across the water tunnel the gauze is su behind by a grid work of fine metal rolle filtering gauze banding is ruled with tra numbered lines, two inches apart. The b are wound on by the action of a propeller passing water outside, so that for every mil through which the instrument is towed section of gauze samples the plankton,

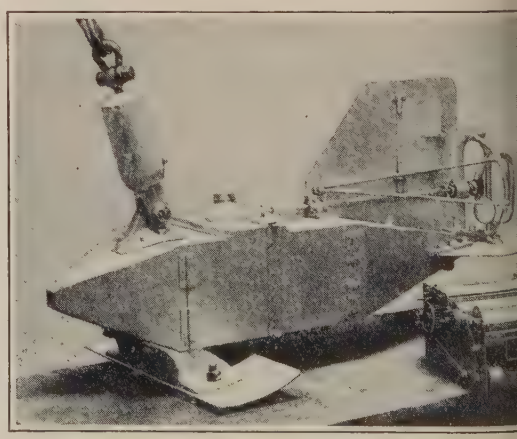


Fig. 1. The Continuous Recorder

Note the diving planes, the entrance to water-t front, and the propeller behind for driving the mechanism, which, for the purpose of the photog been taken out and placed alongside to show th of rollers.

ressed against it till it meets the second
d is imprisoned between the two. The
ollers grip the banding only at their
nich are free from plankton. In the
preservative chamber the fabrics are wound
ige roller operated by a friction drive, so
is no acceleration in winding speed due
sing diameter. At the end of a run the
ken out, placed in a special examination
ich separates the two fabrics and allows
kton to be examined *in situ* under a
microscope. The number of organisms
on of silk can thus be estimated, and since
number of miles travelled is known from
log the distance of sea represented by
sion of silk is known. The pitch of the
blades may be adjusted, so that the speed
g and thus the scale of working may be
om one to more miles per division as

g obtained the kind co-operation of
steamship lines and their officers, and
the ships with special winches, davits,
andling the machines, we began, after a

Fig. 2.
uous plankton recorder (ringed with white) as
ie s.s. *Albatross* between Hull and Bremerhaven,
ready for lowering away.

preliminary trials, a programme of sur-
ie southern North Sea, in June, 1932.
ows the recorder on the S.S. "Albatross"
tween Hull and Bremerhaven. The main
the survey are to chart the broad monthly
n the density of the plankton along a
lines across the North Sea run as nearly
able at the same time, to correlate as far
le the seasonal and yearly variations
with changing hydrological and meteoro-
onditions on the one hand, and with
ns in the fisheries on the other, and in
o provide extensive material for the study
gical relationships between different

members of the phyto- and zooplankton. As far as possible lines have been run every month between Hull and the Skagerak, Hull and Bremerhaven, and Hull and Rotterdam, and more recently a fourth quarterly line between Hull and the Pentland Firth has been added. The instruments are set ready for action in the laboratory before being sent to the ship, put overboard on leaving the coast and taken in on the other side by the officer in charge, definite points, usually lightships, being chosen to mark the beginning and end of a run. When a mark on the wire towing-rope is veered to the water-line the instrument swims at a constant depth of 10 metres.

Space will only permit of a few examples of results being given; later, when four or five years' work has been completed, a full report will be published jointly with my colleagues Dr. G. T. D. Henderson, Mr. C. E. Lucas and Mr. J. H. Fraser, who have carried out the analyses. The correlations with hydrology, meteorology and fisheries will then be dealt with. The present examples are only intended to illustrate the types of changes in distribution we are finding.

With our limited staff it is impossible at present to analyse the plankton in complete detail. Already records of some 20,000 miles of plankton have been made. Whilst we are paying particular attention to the different species of the larger phytoplankton (the smaller forms not being adequately sampled by the mesh we are at present using), we are only attempting to record the changes in density of the main groups of zooplankton: total Copepoda, *Sagitta*, *Limacina*, *Evadne*, *Podon*, etc. The plankton for each section of the rolls is however removed and stored separately, so that any line may be worked up in fuller detail if later it is required and time is available. A rough estimate of the proportions of the common species of Copepoda is however recorded for each section. Such limitations in analysis are to be regretted, but we hope that information regularly obtained regarding the variations in the production of the main groups of plankton organisms in different seasons and in different years will throw new light on the fundamental changes taking place in the area investigated.

Fig. 3 shows examples of the changes in production of Phytoplankton, Dinoflagellates (largely *Ceratium)*, and Copepoda during four months on 182 miles of the Hull—Bremerhaven line, between the Outer Dowsing and Borkum Lightships (vertical lines left and right respectively).

Fig. 4 shows the changes in Copepoda and phytoplankton patches in the autumn of 1933.

Fig. 5 shows the varying density of *Phaeocystis*, *Rhizosolenia styliformis* Brightw., and *Biddulphia sinensis* Grev. on the Hull—Bremerhaven line during 1932, 1933 and 1934, the vertical lines left

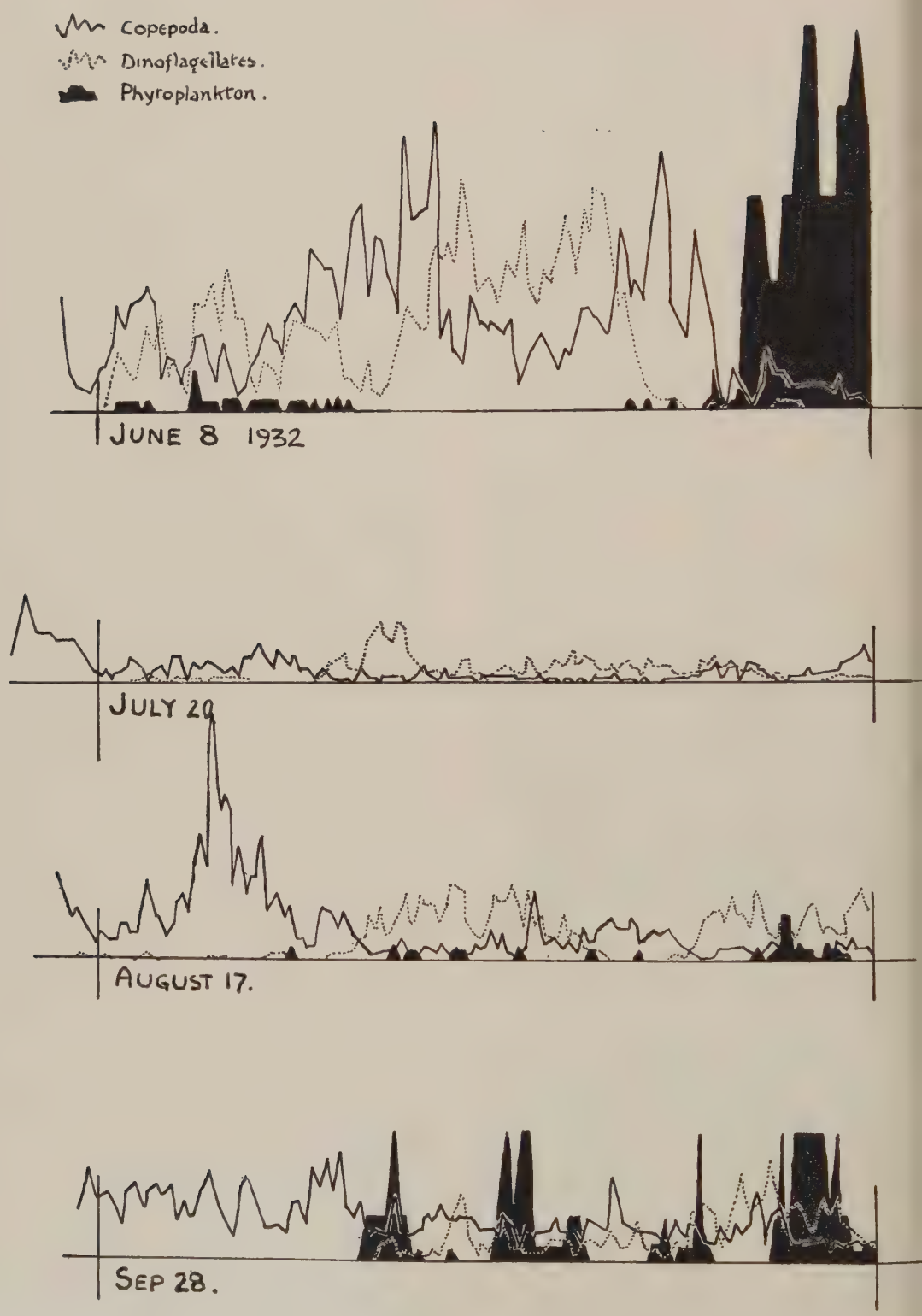


Fig. 3.
Comparative graphs showing variations in the plankton during four months on 182 miles of the Hull—Bremerha between the Outer Dowsing and Borkum Lightships (shown as vertical lines left and right respectively): Copepod flagellates (largely *Ceratium*) and other Phytoplankton (Diatoms, except for *Phaeocystis* at eastern end of Ju

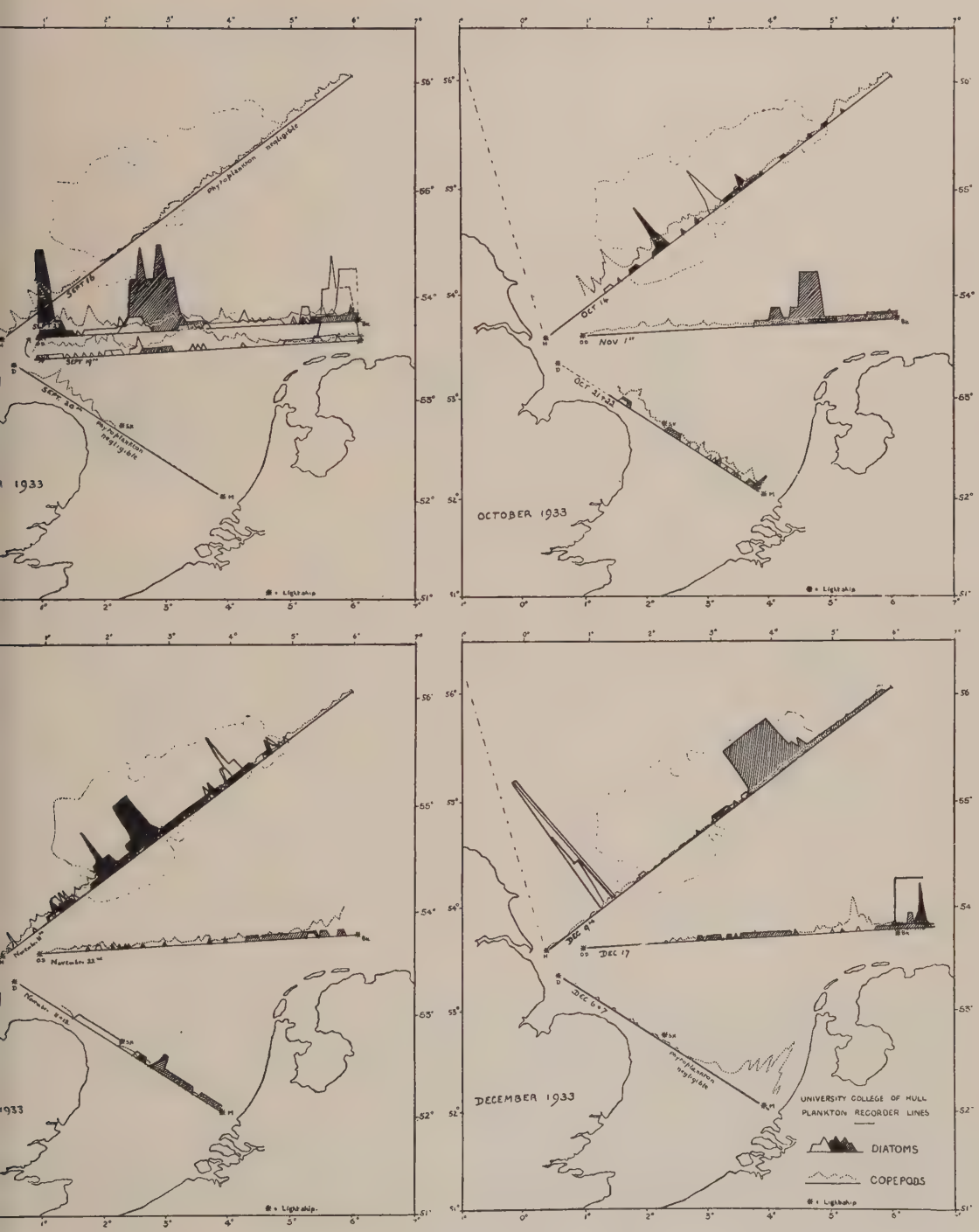


Fig. 4.

wing diatom patches on the Hull—Skagerak, Hull—Bremerhaven and Hull—Rotterdam lines during the autumn *Rhizosolenia styliformis* shown black, *Biddulphia sinensis* shaded, other species in line. In addition the total Copepoda are shown by dotted line.

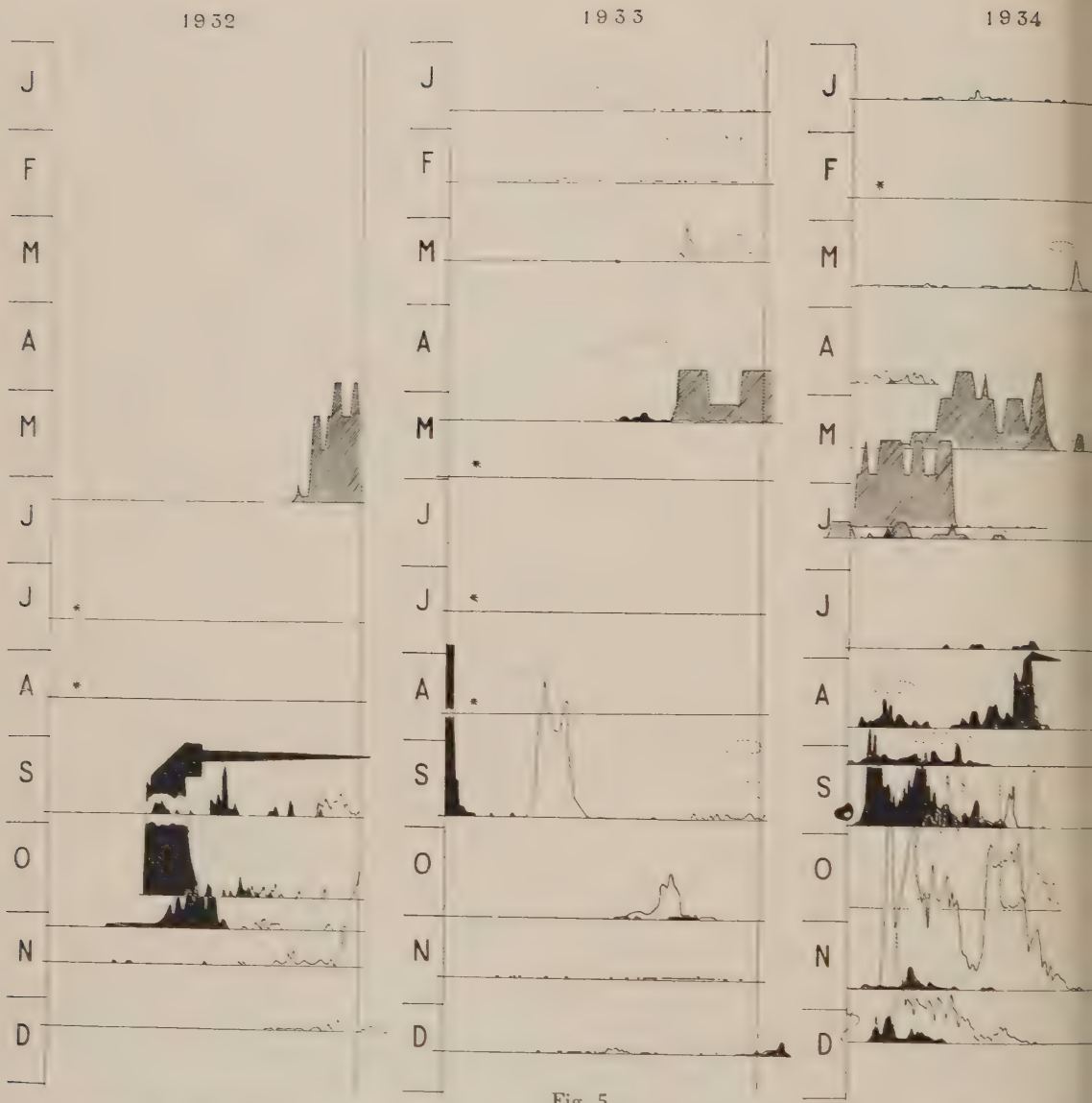


Fig. 5.

Graphs showing the varying density of *Phaeocystis* (shaded), *Rhizosolenia styliformis* (black) and *Biddulphia sinensi* on the Hull—Bremerhaven line during the years 1932, 1933 and 1934. Concentrations of smaller species shown encl broken lines. An asterisk indicates phytoplankton is negligible.. The records are arranged in their correct time p in relation to the scale of months at the side, shown as J, F, M etc. The positions of the Outer Dowsing and Lightships are shown by the vertical lines left and right respectively.

and right again marking the position of the Outer Dowsing and Borkum Lightships respectively. A time scale in months marked J, F, M etc. is given at the side and the records drawn in opposite their appropriate dates. Figs. 6, 7 and 8 in a similar manner show the varying densities of Dinoflagellates (largely *Ceratium)*, Copepoda and *Sagitta*. Similar charts, not shown, have been prepared for other lines. They illustrate clearly the broad changes in plankton production, which it is the aim of the method to reveal: for examp greater production of Copepoda and *Sagitta* late autumn of 1932 as compared with t subsequent years, the repeated increase in poda towards the east in the early months and 1934, which is confirmed again in the year, the dying down and reappearance of a crop of Dinoflagellates in 1934, and the differences in phytoplankton production three years. The probable importance o

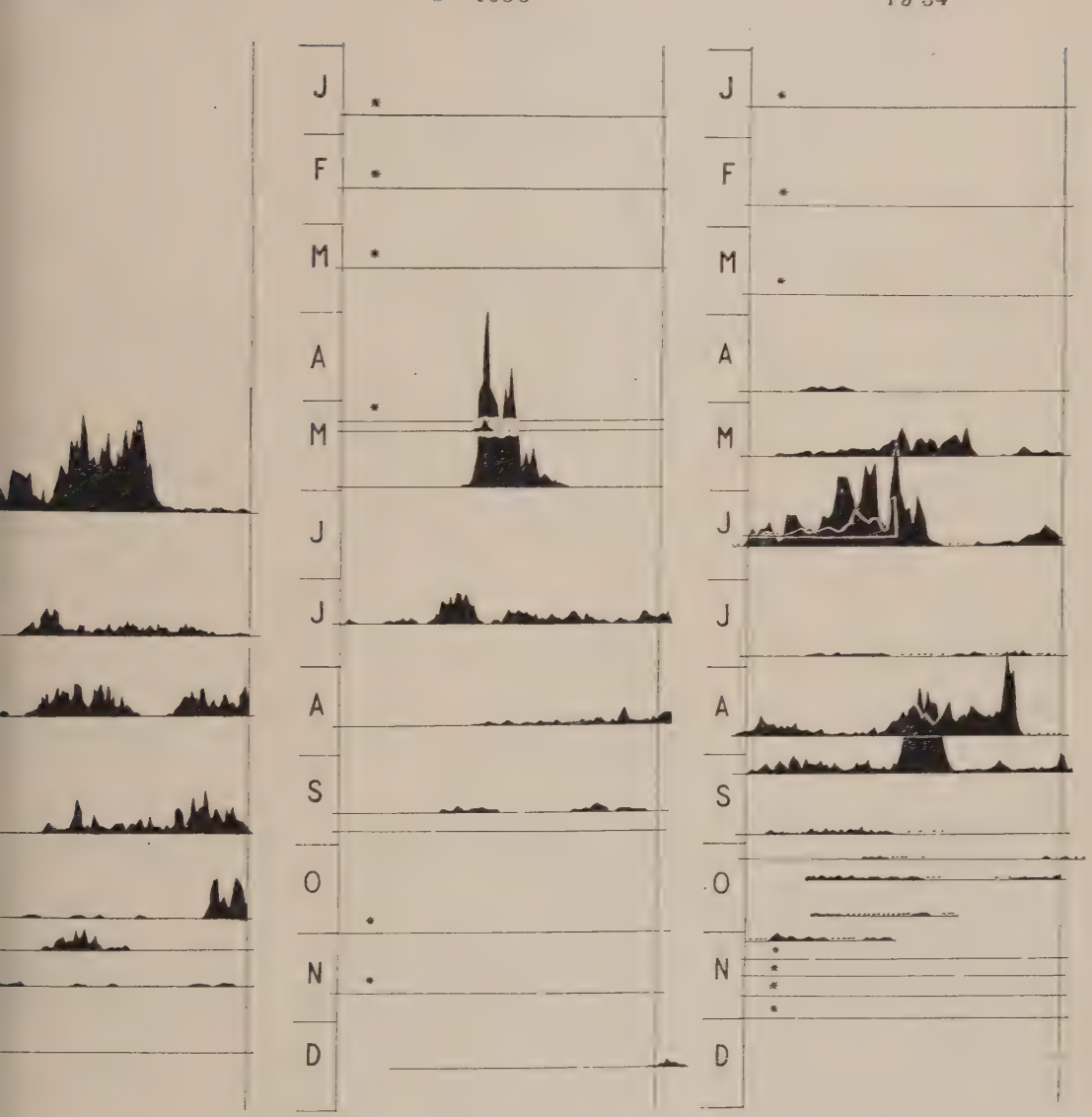


Fig. 6.

wing the varying density of Dinoflagellates (mainly *Ceratium*) on the Hull–Bremerhaven line during the years nd 1934. An asterisk indicates Dinoflagellates are negligible. The records are arranged in their correct time relation to the scale of months at the side, shown as J, F, M etc. The positions of the Outer Dowsing and Borkum Lightships are shown by the vertical lines left and right respectively.

ton patches to the East Anglian herring s recently been demonstrated (S a v a g e y 1935). We are working in close co- with the Ministry of Agriculture and who are carrying out more detailed these patches from research ships. Fig. 9 nore intensive study of these patches on weekly lines in the autumn of 1934. tinuous recorder is in no sense intended o the older methods of research. but we hope it may be regarded as a supplementary method indicating in outline the larger changes characterising the different seasons and different years. We hope it may be the means of establishing a service of *marine phenology*. in that from year to year standard records will be available from different parts of the North Sea of the dates when this or that organism reaches a certain degree of density or when a decline sets in. We hope too that the knowledge of the meteorological. hydrological and

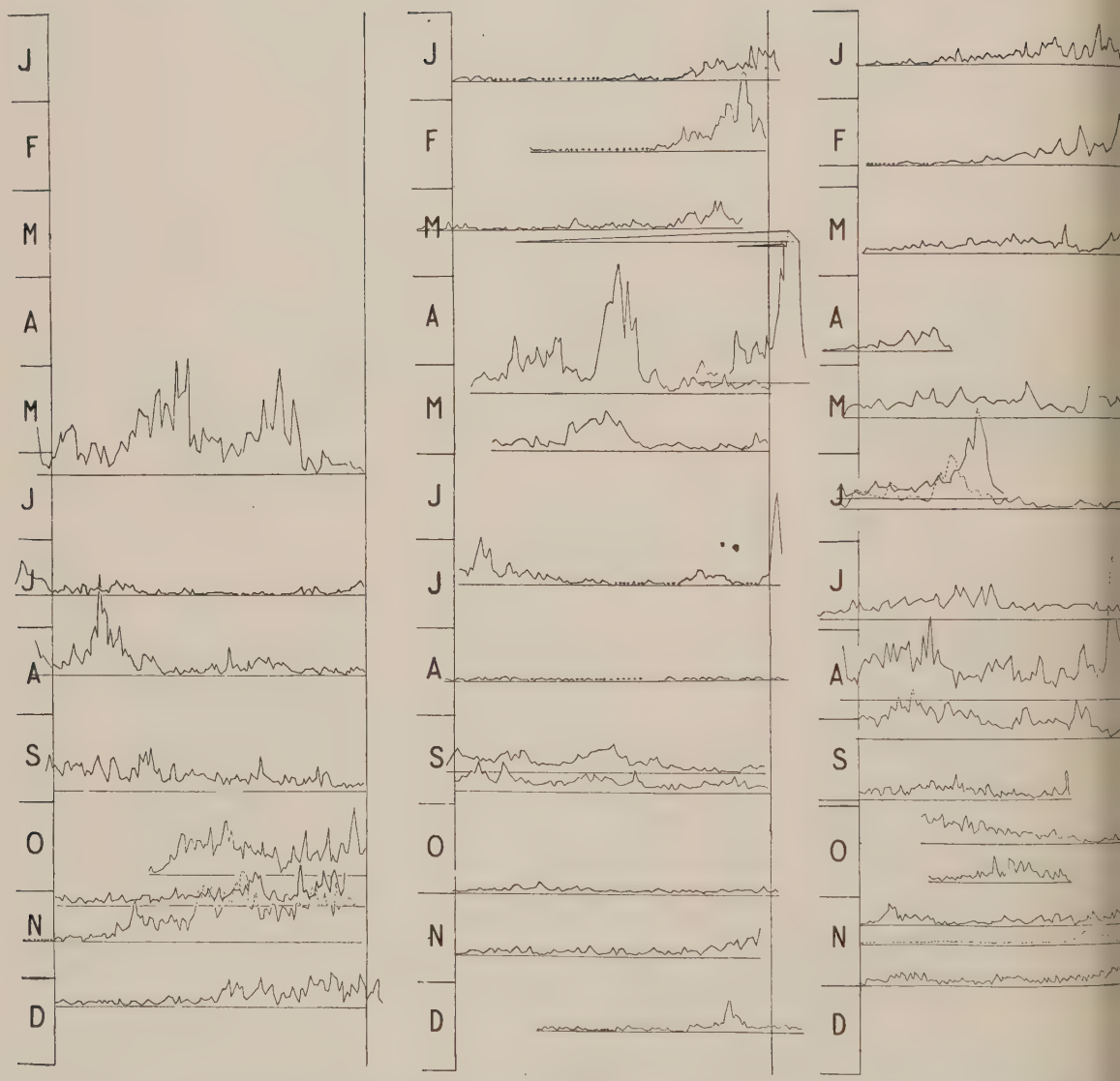


Fig. 7.
Graphs showing the varying density of total Copepoda on the Hull—Bremerhaven line during the years 1932, 19
1934. The records are arranged in their correct time positions in relation to the scale of months at the side, sh
J, F, M etc. The positions of the Outer Dowsing and Borkum Lightships are shown by the vertical lines left an
respectively.

biological correlations, built up over a number of years, will reveal some of the causes governing the major fluctuations.

As in all methods, there are disadvantages. There are, we believe, two major ones. Firstly, in regions of rich plankton the small filtration area of the silk is apt to become somewhat clogged, so that filtration and catching power are reduced. This difficulty applies, although to a lesser extent, in ordinary tow-nets. We believe, however, is not a serious one. It means that wh organisms are taken in very large numbe must realise that the actual numbers present sea are very much larger.

The second and more serious difficulty due to the use of only one instrument makin cord at a uniform depth when some of the org are carrying out diurnal vertical migrations

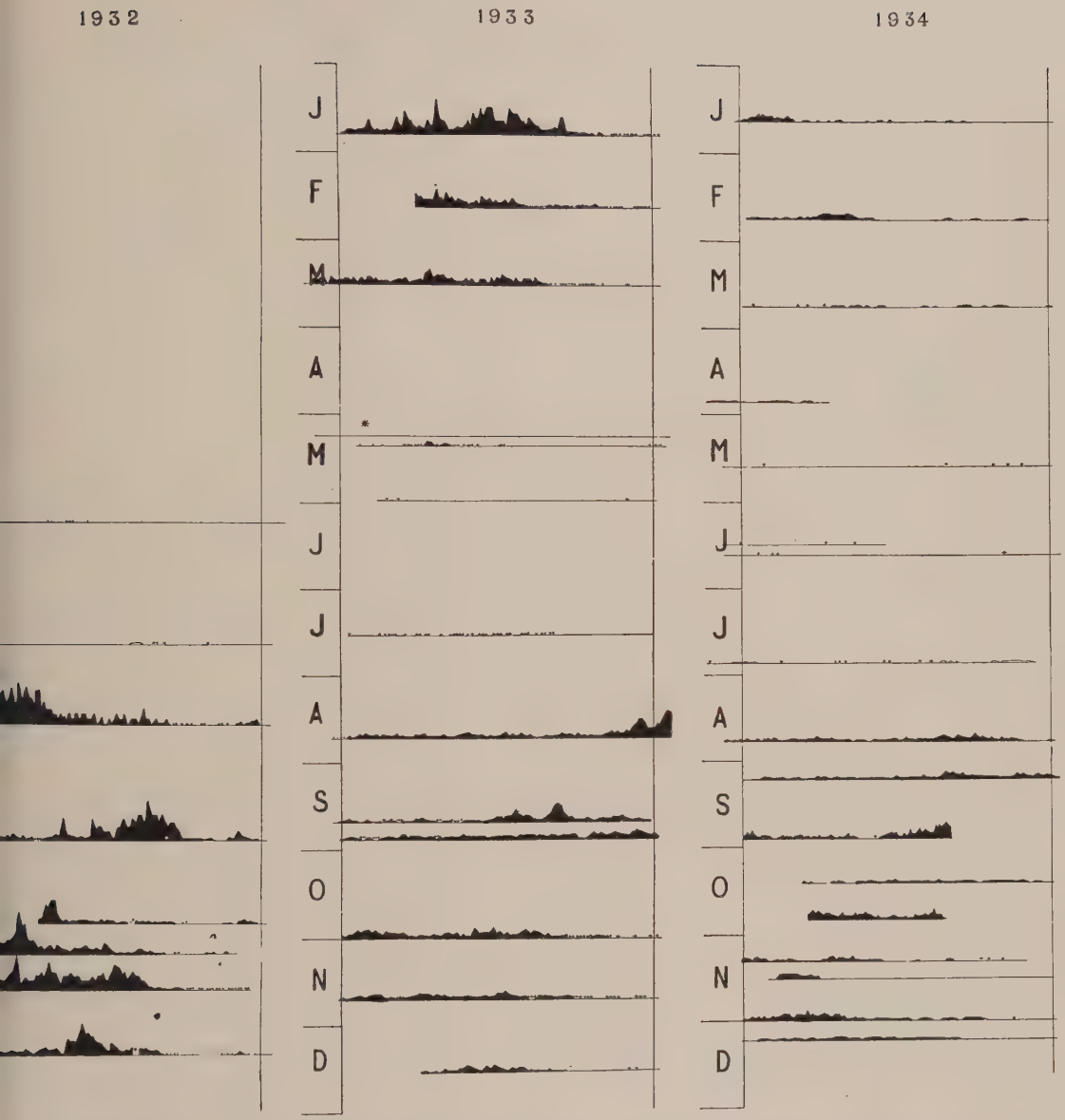
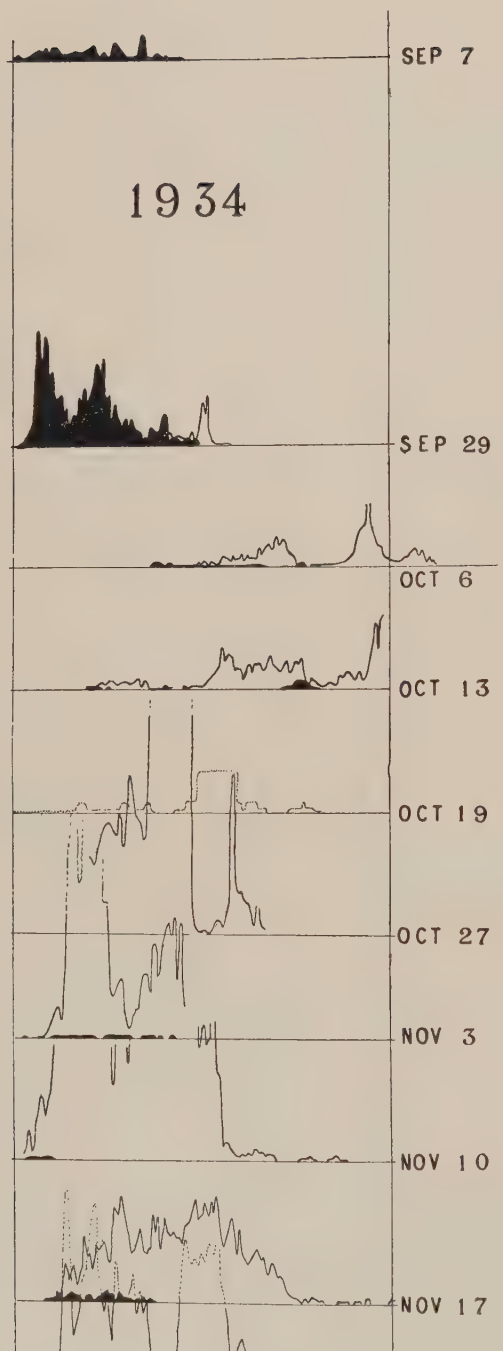


Fig. 8.
owing the varying density of *Sagitta* on the Hull—Bremerhaven line during the years 1932, 1933 and 1934. k indicates that *Sagitta* is negligible. The records are arranged in their correct time positions in relation to f months at the side, shown as J, F, M etc. The positions of the Outer Dowsing and Borkum Lightships are shown by the vertical lines left and right respectively.

depth of towing is 10 metres, chosen for ern North Sea as the most suitable depth ost consistent results. An ideal arrange- ld be the towing of two instruments, one other, at a convenient depth apart. Their he moment precludes this. Mr. J. O. has recently made the very interesting that it might be possible to alter continually the tilt of the diving plane by a cam action from the driving mechanism, so that the instrument oscillates regularly in depth once or twice for each mile covered, thus giving a similar effect to an oblique tow-net haul. Whilst maintenance of stability may be difficult to achieve under such conditions, it should not be impossible, and experiments will shortly be made in this



direction. Actually, on the results (from 10 depth) we are obtaining from the shallow r of the southern North Sea, differences i quantity of zooplankton at different times alo lines of observation do not suggest a n influence through vertical migration. Fig. 10 the Hull—Bremerhaven Copepod records ar with the mid-day points directly below each the positions of sunrise and sunset are sho dotted lines. If vertical migration were prono then there should be a general tendency for and smaller quantities to be taken in relat times of day. Considerations of vertical mig cannot be held to explain the major differe plankton production illustrated in the s figures 5 to 8. More serious are the variati the general depth distribution of the plank different seasons and in different years, givin impressions of relative density of populations factor emphasises the importance of Mr. Borley's valuable suggestion into pr

Another disadvantage of the method condition of the specimens; they are often c and broken in the process of winding, ren identification a longer and more tiring proce the examination of ordinary tow-net samples too is a difficulty which we hope will in fut largely overcome by improved mechanis should be noted that the plankton is not m between the driving rollers, which do not together, except at their ends where they tightly the edges of the silk.

Important points for discussion by tologists are those concerned with size of detail of analysis and scale of working adopted. Given a limited number of worke time available, one may choose between a detailed analysis and larger scale of workin more miles per division of silk), and a less d analysis but smaller scale of working (fewe per section). At present we are working on of 1.5 to 2 miles per section. It will be r that if one section of silk is wound on fo mile of sea passing the machine, then that will collect plankton not only from one r water, but it will also sample a fraction preceding and succeeding miles as well. when the plotted curve of results shows irregularities, it is in reality a smoothed effe the irregularities in the sea are even mor nounced. A closer approximation to th irregularities can be obtained by calcu Whilst the mileage per section varies sligh different runs, the graphs of results are

Fig. 9. Graphs showing a more intensive study varying density of *Rhizosolenia styliformis* (bla *Biddulphia sinensis* (in line) on the Hull—Brem line during the autumn of 1934. The position Outer Dowsing and Borkum Lightships are show vertical lines left and right respectively.

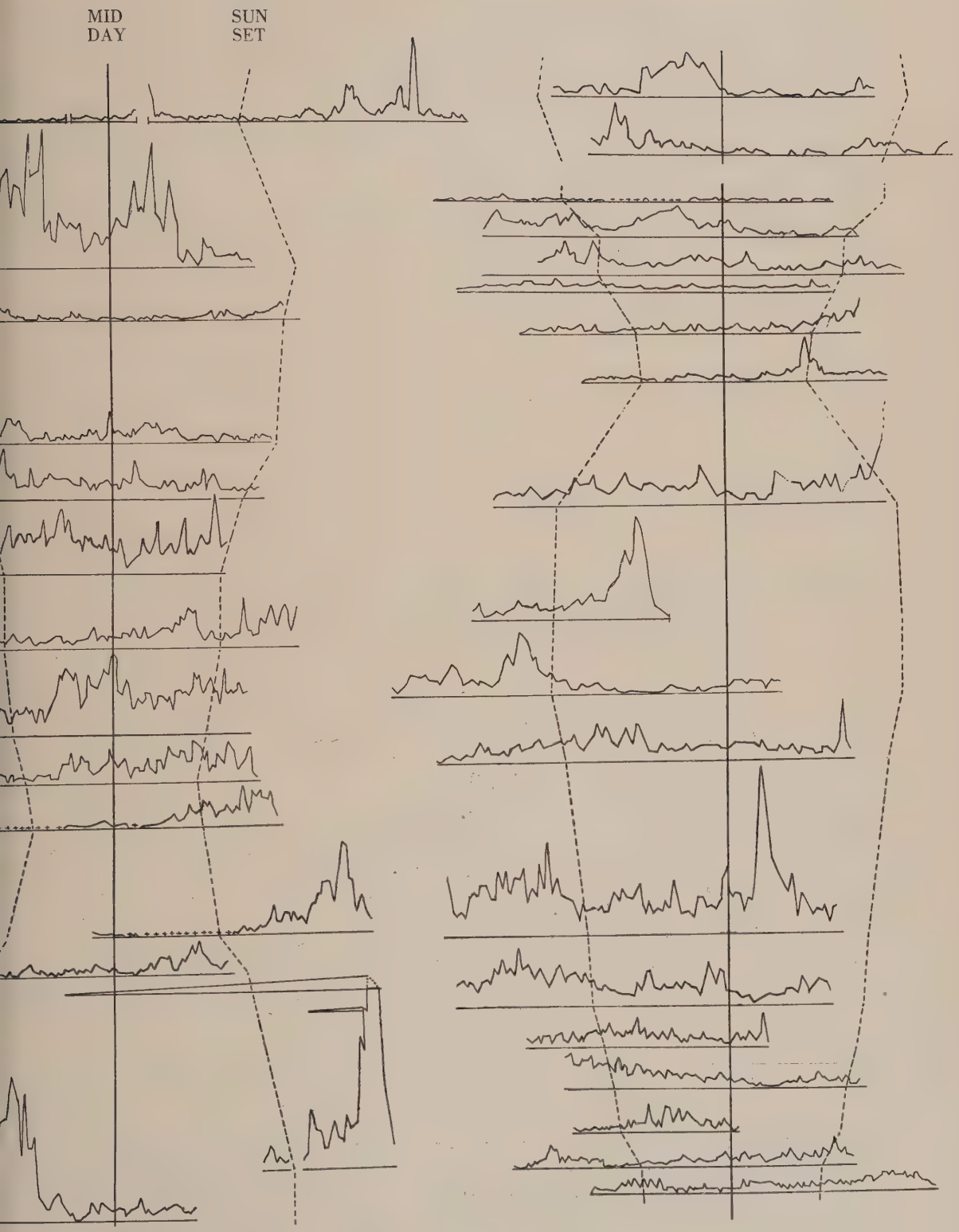


Fig. 10.

raphs from the Hull—Bremerhaven line arranged so that their mid-day points are directly below one another
al line). The dotted lines show the positions of sunrise and sunset. For further explanation see text p. 44.

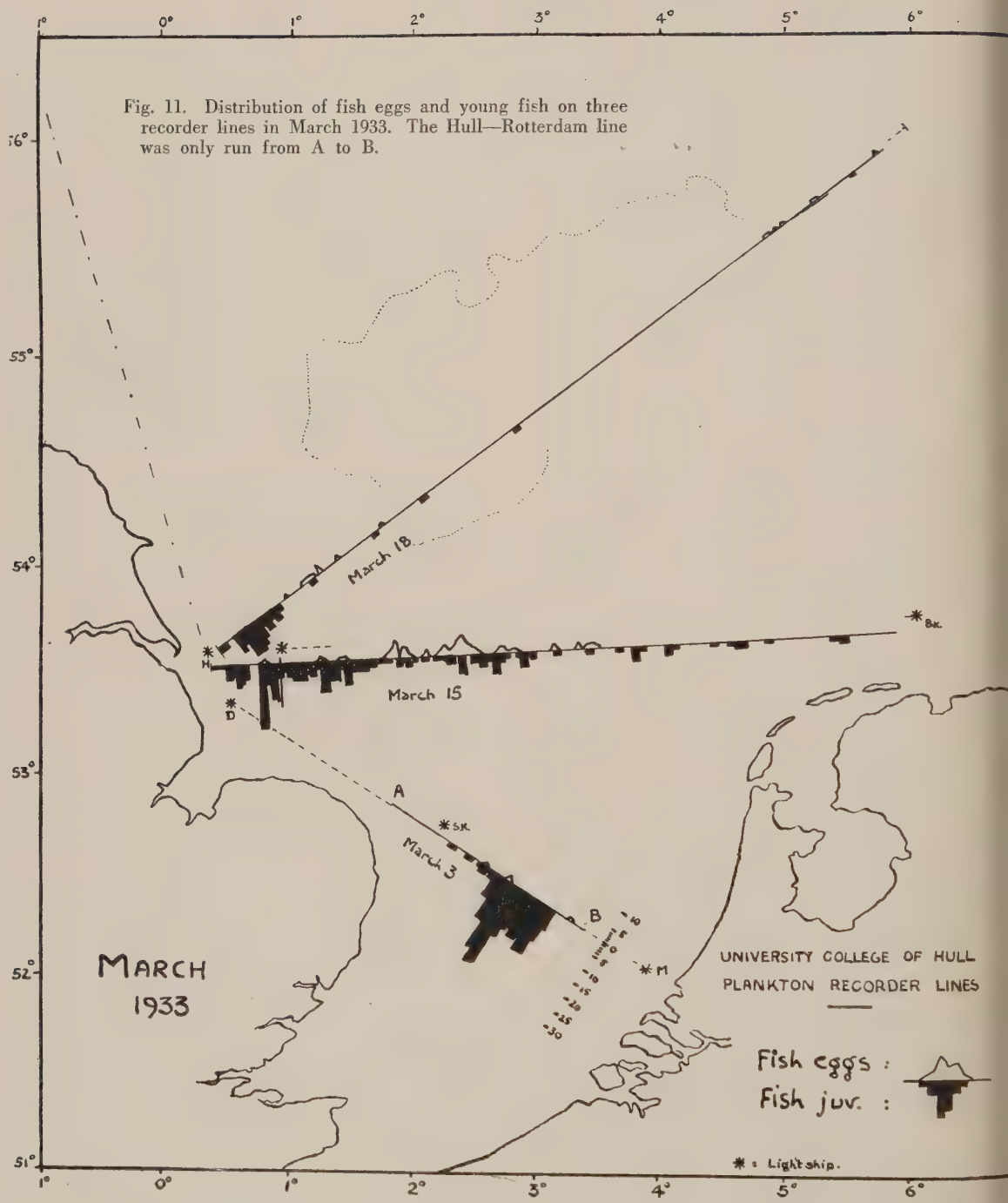


Fig. 11. Distribution of fish eggs and young fish on three recorder lines in March 1933. The Hull—Rotterdam line was only run from A to B.

comparable by plotting the values as numbers per mile for each division.

The mesh of 60 threads to the inch was chosen as one which would effectively sample the Copepoda and at the same time record the denser patches of the larger phytoplankton organisms, which are probably of such importance t herring fisheries. It is hoped in later mod combine with the present system a narrower ing of very much finer gauze for the sm phytoplankton. Rolls of much wider mesh cou used with a larger opening to the water tunn

e of larval and post-larval fish in larger
Fig. 11 shows an example of young
ish egg distribution as obtained with the
perture (¾″ square) and mesh. It is
the survey work advances to be able to
a runs with larger aperture and wider
that perhaps three times the quantity of
ld be sampled for the better estimation
fish and fish egg production.
pe that the lessons we are learning from
riments and from the criticisms of those
will enable us to provide an improved
service of value to the International Investigations, and that in time the means may be found for extending the lines of observation, particularly to include more of the lines upon which monthly thermograph records are now being taken.

References.

Hardy, A. C., 1926. "A new method of plankton research." *Nature* CXVIII, p. 630.

Savage, R. E. and Hardy, A. C., 1935. "*Phyto-plankton and the Herring.*" Part I. Min. of Agric. and Fisheries, Fish. Invest. Ser. II, XIII.

DIE ERGEBNISSE DER INTERNATIONALEN HYDROGRAPHISCHEN BEOBACHTUNGEN IM KATTEGAT IM AUGUST 1931.

VON

BRUNO SCHULZ,

Hamburg, Deutsche Seewarte.

Received March 1936.

[zu einer richtigen Beurteilung der inter-
ationalen hydrographischen Zusammen-
rbeit im südlichen Kattegat im August
kommen, ist es vielleicht nützlich, sich die
nsten Leitlinien zu vergegenwärtigen,
bei einem Überblick über die hydro-
en Arbeiten des Zentral-Ausschusses für
rnationale Meeresforschung festzustellen
bei zu beachten ist, dass für die von der
rschung organisierten Arbeiten nur solche
in Frage kommen können, zu deren Be-
eine internationale Zusammenarbeit
swert oder notwendig ist.
Zeit der Gründung der Internationalen
rschung war man über die Hydrographie
westeuropäischen Fischereigebiete wenig
et, man besass noch nicht einmal einwand-
beitsmethoden für die wichtigsten hydro-
en Faktoren. Daraus ergab sich *eine*
für die hydrographische Arbeit, nämlich
ng der Frage *der Arbeitsmethoden.* Auf-
der Hydrographischen Tabellen, Ein-
des Normalwassers, Verbesserung des In-
riums wurden in der Folgezeit erreicht.
jüngster Zeit noch wurde nach dieser
weitergearbeitet; die Diskussionen auf
enschaftlichen Tagungen über die Me-
er Strommessung, die Bestimmung der
enen Stickstoffverbindungen, der Kohlen-
bren, der Phosphorverbindungen und end-
Versuch, eine Vereinheitlichung der
en Nomenklatur herbeizuführen, sind Bei-
erfür.
zweite Richtung folgerte aus der Not-
lt, die mittlere Verteilung sowie die zeit-

liche Veränderung der hydrographischen Faktoren in den Fischereigebieten zu kennen. Auf den im Februar, Mai, August und November von 1902 bis 1914 durchgeführten Terminfahrten wurde ein reichhaltiges und wertvolles Beobachtungsmaterial vor allem über Temperatur, Salz- und Sauerstoffgehalt in der Nord- und Ostsee gesammelt. Dieses bildete die notwendige Grundlage für zahlreiche Einzelarbeiten sowie besonders für die neueren Darstellungen der mittleren Verteilung von Temperatur und Salzgehalt an der Oberfläche und in der Tiefe der Nord- und Ostsee.

Sehr bald drängte sich jedoch die Erkenntnis auf, dass für eine Darstellung der Verteilung der hydrographischen Faktoren im *Einzelfalle* das Beobachtungsnetz der Terminstationen nicht dicht genug war[1]), sowie ausserdem, dass die Kenntnis der mittleren Verhältnisse durchaus noch keinen Schluss auf den hydrographischen Zustand in einem bestimmten, gerade interessierenden Zeitpunkte gestattet; es entstand daher die Frage, für ein wie grosses Gebiet und einen wie langen Zeitraum kann eine einzelne Serie als repräsentativ angesehen werden. Die regelmässige internationale Zusammenarbeit in der Gewinnung hydrographischer Beobachtungen auf den Terminstationen wurde nach der Unterbrechung im Jahre 1914 nicht wieder aufgenommen; die tiefere Ursache hierfür dürfte im oben angeführten Grunde liegen. Statt dessen aber wurden in Einzeluntersuchungen möglichst weitgehend synoptische Bilder der Verteilung von Temperatur und Salzgehalt in Teilgebieten der nordwesteuropäischen Meere gewonnen. Als Beispiele seien die Arbeiten in der südlichen Nordsee, der Ostsee und im Barentsmeer genannt.

---

nd-Hansen und Nansen, The Norwegian
lo 1909, S. 128. The horizontal distribution of
and temperature in the sea is very complicated,
ich more "irregular" than has hitherto been
l. The conditions may often vary considerably
es with short distances between them. It is
tively easy, for instance, to draw the isohalines
therms in surface-charts, if the observations be
l far apart. The equilines will then have very
distinct and regular shapes, and it appears to be easy to draw general conclusions as to the horizontal distribution and movements of the different waters. But if there be numerous surface-observations, the task becomes much more difficult, and it is often impossible to say with certainty how the curves ought to be drawn. The picture thus obtained may be quite different from that which was based upon few observations; and it proves that the conclusions drawn from the few observations were more or less erroneous.

Die im August 1931 im südlichen Kattegat durchgeführten Untersuchungen stellen die erste seit dem Aufhören der regelmässigen Besuche der Terminstationen erfolgte internationale Zusammenarbeit grösseren Umfanges in praktischer hydrographischer Arbeit dar. Da der Plan die Ausführung von hydrographischen Serien für eine Zeit von acht Tagen in zweistündigem Abstande an fünf nahe benachbarten Punkten vorsah, waren die Beobachtungen geeignet, über die oben aufgestellte Frage, für welches Gebiet und welchen Zeitraum eine einzelne Serie als gültig anzusehen ist, Aufschluss zu geben; insofern lagen die Untersuchungen auf der gleichen Linie der bisherigen internationalen Arbeiten. Der unmittelbare Anlass aber war gegeben durch den Wunsch, die Vorgänge beim Wasseraustausch zwischen zwei Meeren mit verschiedener Ausbildung der hydrographischen Verhältnisse möglichst eingehend zu verfolgen, insbesondere die Ausbildung der internen Wellen an den Grenzschichten. Weiterhin aber waren die Diskussionen über die Frage der Vorgänge bei der Mischung verschiedener Wasserarten, welche durch die Internationale Meeresforschung angeregt worden waren, die Veranlassung, die Untersuchungen über den Wasseraustausch so anzulegen, dass sich gleichzeitig möglichst eingehende Einblicke in die Mischungsvorgänge erwarten liessen.

An den Arbeiten waren fünf Schiffe beteiligt; sie waren acht Tage hindurch und zwar vom 10.—17. August 1931 an den im folgenden angegebenen Positionen verankert:

"Japetus Steenstrup" (dänisch)	56°22.4′ N Br..	12°02.5′ O Lg.
"Skagerak" (schwedisch)...	56°23.3′ N Br.,	12°13.5′ O Lg.
"Nautilus" (finnländisch) .	56°18.3′ N Br.,	12°08.0′ O Lg.
"Hunte" (deutsch)	56°26.2′ N Br.,	11°53.8′ O Lg.
"Poseidon" (deutsch)	56°21.0′ N Br.,	11°59.1′ O Lg.

Das Untersuchungsgebiet liegt dicht vor dem Nordausgange des Sundes und hat Tiefen von 30 bis 32 m. Das Programm bestand im wesentlichen darin, vom 10. VIII. 18^h bis zum 17. VIII. 18^h hydrographische Serien und Strommessungen in zweistündigem Abstande in 0, 5, 10, 15, 20, 25 m. Tiefe und dicht über dem Boden auszuführen. Die tatsächlich gewonnene Beobachtungsdichte war auf einigen Schiffen dichter als vorgesehen. Um über die hydrographische Lage im weiteren Untersuchungsgebiet vor und nach der Verankerungszeit einen Überblick zu gewinnen, beteiligten sich alle fünf Schiffe daran, auf der Hin- und Rückreise an vereinbarten Orten hydrographische Serien zu gewinnen. Ausserdem wurde auf den Feuerschiffen im Kattegat sowie im Grossen Belt und Sund ein intensiverer Beobachtungsdienst als normal durchgeführt, auch erfolgten Wasserstandsmessungen an zahlreichen Punkten des in Betracht kommenden Bereiches. Über die Einzelheiten der tatsächlich durchgeführten Arbeiten sowie der angewa Methoden ist bereits ausführlich berichtet w auch liegt das gewonnene Material veröffe vor; hierauf sei verwiesen[1]).

Über die gewonnenen Ergebnisse liegen m Spezialveröffentlichungen vor[2]). Im folgend versucht, unter deren Benutzung einen zusa fassenden Überblick über die wichtigsten der der einzelnen Verfasser gewonnenen Ergebni geben.

Hierbei ist es am vorteilhaftesten, von gemeinen zum Speziellen überzugehen, also v das gesamte Kattegat betreffenden Erschein auszugehen und dann zu den an den Veranke stellen festgestellten fortzuschreiten. Zunächs die Zustände an der Oberfläche betrachte zwar auf Grund der sich zeitlich am weiteste dehnenden Beobachtungen, nämlich der Fla posten. Während der ganzen Verankeru wurden von jedem Schiffe gleichzeitig zu vollen Stunde mindestens je eine und mitt

---

[1]) Bruno Schulz, Vorläufiger Bericht über di nationalen hydrographischen Untersuchungen i lichen Kattegat im August 1931, insbesondere ü auf R.F.D. "Poseidon" ausgeführten Arbeiten. Hydr. 1932, S. 1—6.

Conseil Permanent International pour l'Exploratio Mer: Bulletin Hydrographique, Appendice du pour l'année 1931. Expédition internationale du du 10 au 17 août 1931. Kopenhagen, 1933. (Ve lichung des Beobachtungsmaterials in extenso: graphische Serien und Strommessungen de Schiffe, der beteiligten Feuerschiffe und Wasse beobachtungen an Küstenpunkten.

[2]) A. Defant und O. v. Schubert, Stromme und ozeanographische Serienbeobachtungen der derunternehmung im Kattegat 10.—17. Augus Veröff. d. Inst. f. Meereskunde, N.F., A. Geogr.- Reihe, Heft 25. Berlin, 1934.

H. Rauschelbach, Die Hochseepegelbeobachtu südlichen Kattegat im August 1931. Ann. d. Hy S. 177—185, 233—250.

H. Geissler, Untersuchungen an der Pyknoson rend der Kattegat-Fahrt mit der "Hunte" im 1931. Ann. d. Hydr. 1934, S. 322—326.

H. Thorade, Über Stromunruhe. Nach Beobac im Kattegat. Ann. d. Hydr. 1934, S. 365—377.

H. Thorade., Beständigkeit und Streuung bei Ann. d. Hydr. 1936, S. 13—23.

Bruno Schulz, Flaschenpostuntersuchungen i chen Kattegat 10.—17. August 1931. Ann. d. Hy S. 1—10.

J. P. Jacobsen, Temperaturmessung mit elek Widerstandsthermometer auf der Kattegatexped August 1931. Medd. Komm. Danmarks Fisk. unders., Ser. Hydrografi, Bind III, Nr. 1. Kop 1935.

H. Thorade, Strombeobachtungen am Nordausg Kattegats. Ann. d. Hydr. 1936, Maiheft.

Bruno Schulz, Die hydrographische Lage im im August 1931. Ann. d. Hydr. 1936, Maiheft.

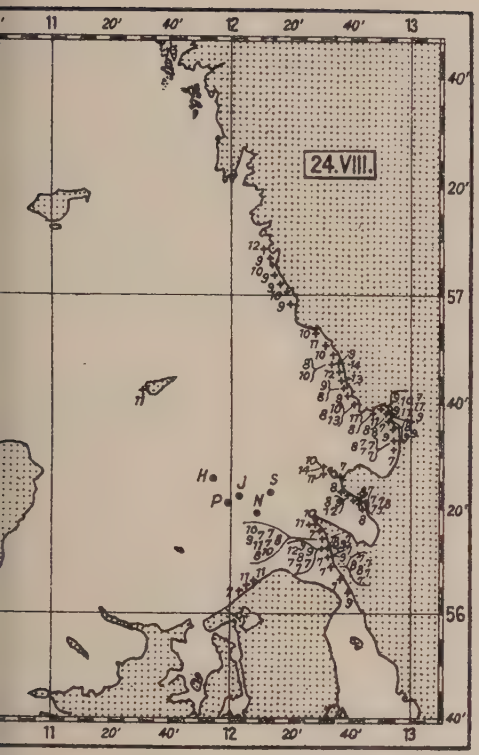


Fig. 1.

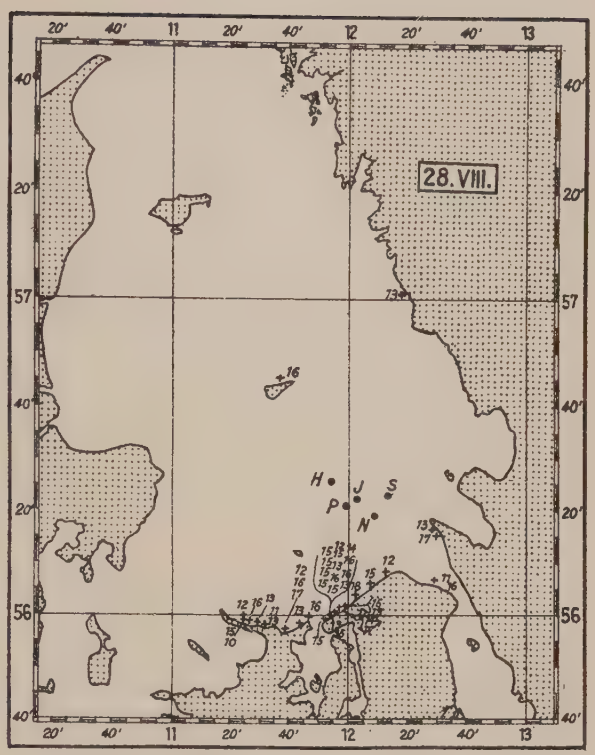


Fig. 2.

er am 24. und 28. August gefundenen Flaschenposten (ausgesetzt vom 10. bis 17. August von den fünf mit gsbuchstaben ihrer Namen bezeichneten Schiffen). Die Fundstellen sind durch Kreuze bezeichnet, die Zahlen wischen Aussetzung der Flaschenposten und ihrer Auffindung verflossene Zeit, also mit hinreichender Genauigkeit die Reisedauer der Flaschenposten an.

chenposten ausgesetzt, insgesamt 1079. n wurden bis zum 25. Oktober 1931, also von etwa neun Wochen, 521, also 48 % nden. Ein Vergleich des Verbleibes der inzelnen Schiffen ausgesetzten Flaschengte, dass der Aussetzungsort von wesentnfluss auf die Triften gewesen ist. Zwei lassen sich unterscheiden; die von "Poseidon" und "Japetus Steenstrup" ausund gefundenen Flaschenposten wurden eicher Zahl westlich und östlich der Ein- Sund angetrieben, die von "Nautilus" gerak" ausgesetzten aber strandeten in er Fälle östlich der Sundeinfahrt. Bei htung der Fundorte *sämtlicher* Flaschenalso ein Einfluss des an der schwedischen lang nach Norden setzenden Baltischen weifelsfrei zu erkennen. Anders ist es in Zeiträumen, in denen sich die jeweiligen ltnisse als entscheidend für die Ver- er Strandungsorte der Flaschenposten Bis zum 22. VIII. wurden 17 Flaschen gefunden, an den neun folgenden Tagen vom 23.—31. VIII. je 31, 96, 36, 43, 36, 40, 21, 17 und 16 Flaschenposten, also allein an diesen neun Tagen 66 % aller überhaupt wiedergefundenen Flaschen. Dies liess es aussichtsreich erscheinen, nach Beziehungen zwischen den Windrichtungen und der Verteilung der Fundorte zu suchen. Die am 23. VIII. einsetzenden und auch am folgenden Tage anhaltenden mässigen bis starken Winde aus westlichen Richtungen bewirkten, dass an der schwedischen Westküste Flaschenposten in grosser Zahl antrieben. Die in Figur 1 angegebenen Fundorte der am 24. August aufgefundenen 96 Flaschenposten zeigen dies. Die in den nächsten Tagen herrschenden nördlichen Winde bewirkten einen völligen Umschwung in der Trift der Flaschenposten; die Strandungen erfolgten fast ausnahmslos an der Nordküste von Seeland, hierfür ist die Verteilung der am 28. VIII. gefundenen Flaschenposten (Fig. 2) ein Beispiel. Dies zeigt, dass *im Einzelfalle die Bewegung des Oberflächenwassers grossen Schwankungen unterliegt und ganz andere*

Wasserbewegungen herrschen können als das mittlere Strombild anzeigt. Dass die Fundorte der Flaschenposten aber überhaupt eine derartige Abhängigkeit von den Änderungen des Windes aufweisen, ist nur dadurch möglich, dass die Flaschenposten sich schon bald nach ihrer Aussetzung über das ganze Gebiet des südlichen Kattegats verteilt haben müssen. Diese Erkenntnis dürfte von biologischem Interesse sein, weil sich aus ihr ergibt, *dass auch planktonische Lebewesen, selbst wenn ihre Entstehung nur innerhalb eines kleinen Bezirkes des Kattegats erfolgt, schnell über ein grosses Gebiet verbreitet werden können.*

Sind diese beiden Ergebnisse auch von allgemeinerem Interesse, so liefern doch die Flaschenpostbeobachtungen kein detailliertes Bild der Strömungen und vor allem geben sie wegen der kleinen Zahl der bis zum 17. August wiedergefundenen Flaschenposten keinen Aufschluss über die Stromverteilung während der Zeit vom 10.—17. August, was in diesem Zusammenhange in erster Linie von Interesse wäre.

Einen erheblichen Fortschritt in dieser Beziehung ermöglichen die Wasserstandsbeobachtungen an 12 Orten an den festländischen und Inselküsten des Kattegats, der Beltsee und des Sundes sowie die Strombeobachtungen auf den Feuerschiffen Halskov Rev (Grosser Belt) und Lappegrunden (Sund); sie gestatten eine Bilanz des gesamten Wasseraustausches zwischen dem Kattegat und dem Skagerak sowie der Belt- und Ostsee.

Unmittelbar vor dem Beginn und noch während der ersten Tage der Beobachtungen bis zum 12. VIII. mittags standen Nord- und Ostsee unter dem Einfluss eines über der Ostseeregion lagernden Tiefs, welches über der Nordsee starke, zeitweise stürmische nördliche Winde, im Kattegat und Skagerak nordwestliche, in der südlichen Ostsee westliche und in der mittleren Ostsee südliche Winde bedingte. Die Folge war ein Einströmen von Wasser in das Kattegat. Die dortigen Stationen zeigten zu Beginn der Untersuchungszeit eine starke Erhöhung des Wasserstandes; die höchsten Werte wurden bei Anholt und Halmstad mit 25 cm. über Null festgestellt (Fig. 3). Je näher aber die Stationen der Ostsee liegen, desto geringer ist die Erhöhung; im Grossen Belt und besonders bei Gjedser sind die Werte unter normal wegen der Trift des Wassers aus der südlichen in die nördliche Ostsee. In den ersten Tagen der Beobachtungszeit schwächt sich diese Erscheinung ab wegen des Abflauens der sie verursachenden Winde. Das gleiche ist während der vom 12. VIII. bis zum 14. VIII. mittags dauernden zweiten Windperiode mit uneinheitlicher und im allgemeinen schwacher Luftbewegung der Fall; in der Beltsee steigt der Wasserstand erheblich wegen des innerhalb der Ostsee von Norden zurückfliessenden und aus dem Kattegat nach Süden abfliessenden Wassers. In Gjedser wird am Abschluss dieser zweiten Windperiode der höchste Wasserstand mit 25 cm. über Null erre
Während des am 14. VIII. einsetzenden d
Abschnittes der Luftbewegung mit südwestli
Winden ist die geschilderte Entwicklung w
rückläufig. An den beiden Stationen Anholt
Gjedser sind die geschilderten Veränderunge
Wasserstandes am reinsten ausgebildet; dazwi
sind Übergangserscheinungen angedeutet, am
lichsten in Fredericia. Kennzeichnend hierfü
dass die Summe der Kurven für Anholt und Gj
im Gang mit der Wasserstandskurve von Frede
fast identisch ist (vergl. Fig. 3). *Von allgem*

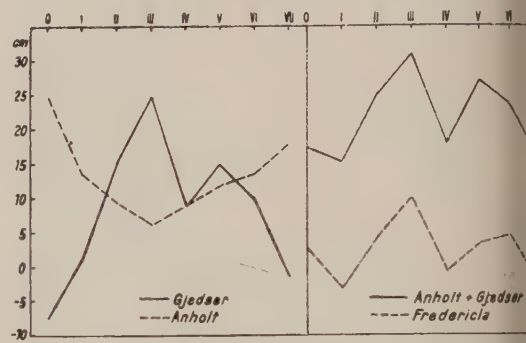


Fig. 3. Mittlere Wasserstände bei Anholt, Gjedser
Fredericia vom 10. bis 18. August 1931 (nach v. S
b e r t).

0 ..... VII bedeuten die Mondperioden während
Tage,

0 Mondperiode ist die Zeit vom 10. VIII. 9^h50
11. VIII. 10^h51^m,

VII Mondperiode ist die Zeit vom 17. VIII. 16^h18
18. VIII. 17^h9^m.

*Bedeutung sind die Ergebnisse der Untersuc
der gleichzeitigen Luftdruckschwankungen,
denen hervorgeht, dass ein Zusammenhang zwi
Luftdruck- und Wasserstandsschwankungen
gends einwandfrei zu erkennen ist, die Winde
in allen Fällen eine ausreichende Erklärung
Wasserstandsschwankungen geben.*

Eine eingehendere Erkenntnis, wie die W
bewegung an den wichtigsten einzelnen Zug
pforten zum Kattegat gewesen ist, liess sich fü
Grossen Belt erschliessen aus der Differenz
Wasserstände zwischen den an der Ost- und
seite des Grossen Belts gelegenen Orten K
und Slipshavn, sowie aus den Strombeobachtu
bei Feuerschiff Halskov Rev und für den Sun
den Strombeobachtungen bei Feuerschiff L
grunden; im Kleinen Belt fehlt es allerding
geeigneten Beobachtungen. Für die durch den
ausgang des Kattegats transportierten W
massen ist eine Schätzung dadurch möglich,
die sich aus den Niveauveränderungen im Ka
ergebenden Wassermassen zu den durch

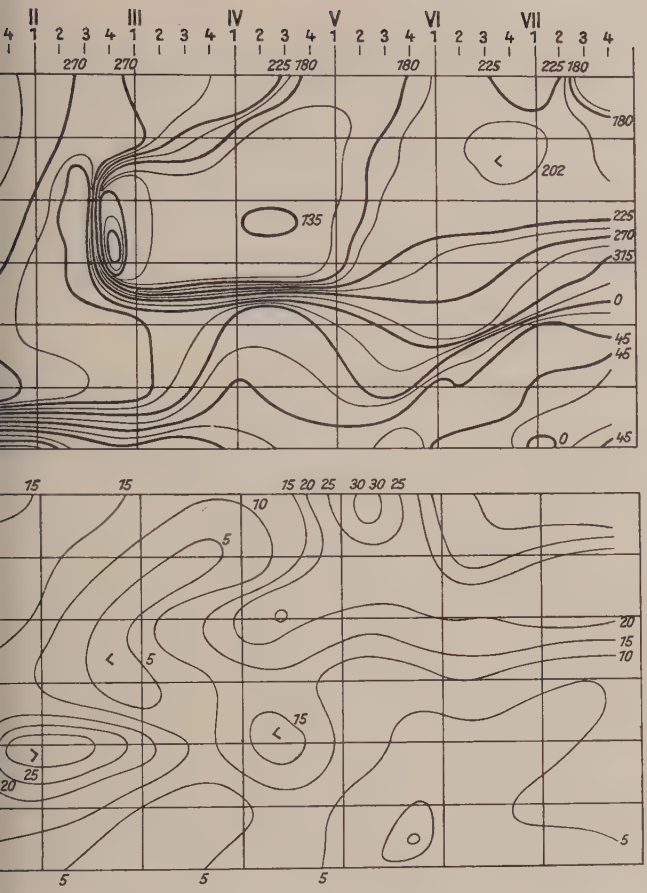


Fig. 4. Isoplethendarstellung der Stromrichtung (Angabe in Graden wohin, also 180° = Strom nach Süden) und der Geschwindigkeit der Restströme (cm./sec.) bei "Poseidon" durch Mittelwerte für je 6 Mondstunden in den Perioden I bis VII (vergl. Erläuterung zu Figur 3), nach A. Defant.

Belt und den Sund transportierten Wasser- in Beziehung gesetzt werden. Hieraus sich, dass in der ersten Hälfte der Beob- szeit der Strom aus dem Kattegat durch lt in die Ostsee, in der zweiten Hälfte in hrter Richtung gegangen ist. Im Sund hat dwärts gerichtete Bewegung kürzere Zeit t, der Nordstrom hat sich weit früher esetzt, wahrscheinlich weil die herrschenden n Winde das im mittleren Kattegat an- Wasser gegen den Belt getrieben und damit eg für den Nordstrom aus dem Sund frei t haben. Durch den Nordausgang des ts hat dagegen im ersten Drittel der ntungszeit ein Zufluss nach dem Kattegat unden und während der übrigen Zeit ein

aus den Strommessungen an den Ver- ngsstellen zu folgernden Restströme stützen h den genannten Methoden gewonnenen An- ngen über die Gesamtwasserversetzungen Selbst die durch Mittelbildung über 6 Mond- von dem Gezeitenstromeinfluss im wesent- lichen befreiten Stromwerte, also die Restströme, sind auf den einzelnen Schiffen sehr stark veränderlich (vergl. die in Figur 4 und 5 gegebenen Beispiele). Zwar ist eine weitgehende Abhängigkeit vom Winde festzustellen und es treten bei den einzelnen Beobachtungsstellen gemeinsame Züge auf, doch ist ungleiches Verhalten überwiegend. Offenbar ist der fortwährende Wechsel der Windrichtung und -stärke so gross, dass auch nur annähernd stationäre Zustände sich nicht herausbilden konnten. Also selbst die über 6 Mondstunden gebildeten Mittelwerte sind nicht für einen grösseren Bereich mit mehreren Seemeilen Durchmesser gültig. Auch bei den über einen vollen Mondtag gebildeten Mitteln sind die Unterschiede zwischen den einzelnen Beobachtungspunkten noch so gross, dass gesetzmässige Beziehungen nicht festzustellen sind. Betrachtet man endlich die für die ganze Beobachtungszeit für die einzelnen Tiefen gemittelten Restströme, so ist festzustellen, dass sogar im allgemeinen Mittel die Stromverhältnisse an den einzelnen Punkten ganz verschieden sind. Die beiden voneinander entferntesten Schiffe "Hunte"

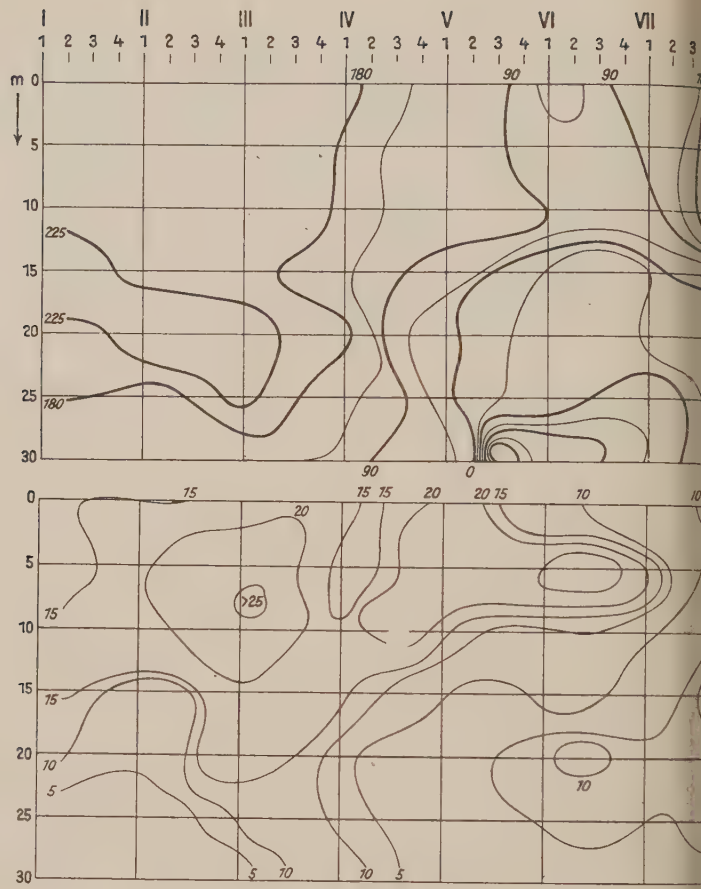
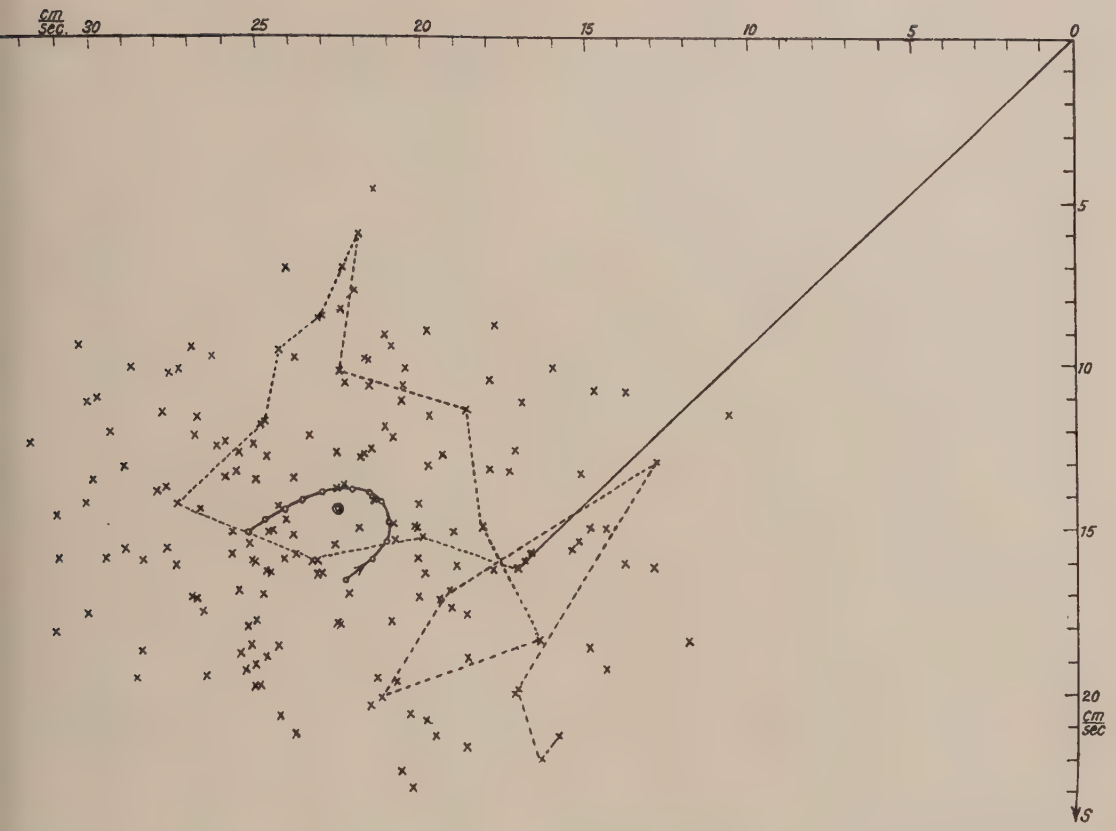


Fig. 5. Isoplethendarstellung der Stromrichtung (Angabe in Graden wohin, also Strom 180° = Strom nach Süden) und der Geschwindigkeit der Restströme (cm./sec.) bei "Nautilus" durch Mittelwerte für je 6 Mondstunden in den Perioden I bis VII (vergl. Erläuterung zu Figur 3), nach A. Defant.

(am weitesten im Norden) und "Nautilus" (am weitesten im Süden) weisen in allen Tiefen Strömungen mit Südkomponente auf. Bei den beiden dazwischen und untereinander am meisten benachbart gelegenen Schiffen "Poseidon" und „Japetus Steenstrup" ist dies nur in der Oberschicht bis 15 m. Tiefe der Fall, darunter herrscht Strom mit Nordkomponente. Auch das allgemeine Mittel über 7 mal 24 Mondstunden ist nicht imstande, die allgemeinen Störungen im sicherlich gleichförmigen Aufbau des Stromes an den nahe beieinander und in ähnlicher Lage gelegenen Stationen auszuschalten. Daraus folgt, *dass aus dem in dem Verankerungsgebiet gewonnenen Bild der Verteilung des Reststromes keine Schlüsse für ein grösseres Gebiet gezogen werden dürfen*, dass also die Grösse des von den Verankerungsstellen eingeschlossenen Gebietes nicht ausreicht für die Erkenntnis der Gesamtwasserversetzung des Kattegats. Dies ist ein Beweis dafür, wie gross und unkontrollierbar die Mischungsprozesse in diesem Meeresraum sind.

Wesentlich verstärkt wird dieser Eindruck noch durch die Strombeobachtungen des "Poseidon", die an drei verschiedenen Stellen des Schiffes mit Rauschelbach'schen Strommesser gewonnen wo sind, bei dem die Stromangaben im Zeitabst von 10 sec. erfolgen. Dabei ergab sich nun, die einzelnen aufeinander folgenden Beobac gen ausserordentlich stark variieren sowohl i Stromrichtung wie in der Stromstärke. Die Urs hierfür wurde gefunden im Seegang, also in Bewegungen des Schiffskörpers, ausserdem ab den Mischungsvorgängen im Meerwasser. Ers Mittel aus fünf Minuten lang fortgesetzten B achtungen sind als zuverlässig anzusehen. W hin ergab sich, dass die Messungen an zwe 10 m. Tiefe und 19 m. Abstand voneinander a brachten Strommessern fast stets verschie Ergebnisse lieferten, dass also schon in d geringen Entfernung die Strömungen mer verschieden waren. Zum geringeren Teile war dadurch verursacht, dass selbst in 10 m. Tiefe Strom noch nachweisbar durch den etwa 3 m. gehenden Schiffskörper beeinflusst wird. Interesse ist in diesem Zusammenhange auch, sich erhebliche Unterschiede in den gemess



Ergebnisse der Aufzeichnungen des Rauschelbach'schen Strommessers von 10 zu 10 Sekunden am 10. VIII. 1931, 19^h00^m an Bord des "Poseidon" (nach Thorade). Die einzelnen Strompfeile sind vom Nullpunkte nach den Kreuzen zu ziehen. Die gestrichelte Linie verbindet die Beobachtungen der ersten drei Minuten. Die ausLinie gibt die Fünfminuten-Mittel an (mit Zwischenschaltung), der Doppelkreis das Gesamtmittel.

gen ergaben, je nachdem sie an der Luveseite des Schiffes gewonnen waren. Bei atsachen ist es nicht verwunderlich, dass "Hunte" gleichzeitig angestellte Stromungen mit dem Relingslog in 0 m. Tiefe einem Strommesser in 1 m. Tiefe sehr efriedigende Übereinstimmung zeigten.

sehr bemerkenswerte Gesetzmässigkeit hat r auf folgende Weise ergeben. Bei Oriender vertikalen Verteilung des Reststromes 'Hunte" nach der gleichzeitig herrschenden ıtung ergab sich ein vertikaler Aufbau des nes, welcher der von V. W. Ekman gei vertikalen Stromverteilung in einem allen Land umschlossenen Meere überraschend ist. Dies lässt den Schluss zu, dass durch elbildung alles Unstationäre ausgeschieden nd die für ein allseitig fast vollständig einsenes Meeresgebiet charakteristische vertiteilung des durch Wind erzeugten Stromes strom übriggeblieben ist. Die grosse Geschwindigkeitszunahme in 20 m. Tiefe dürfte mit der in etwa 17 m. vorhandenen Sprungschicht in Zusammenhang stehen.

Die Beobachtungen von Temperatur und Salzgehalt ergeben für alle fünf Beobachtungspunkte das zu erwartende Bild: nämlich salzarmes Wasser an der Oberfläche und salzreiches Wasser in der Tiefe und dazwischen eine ausgeprägte Sprungschicht, sodass also der Grundzug der seit langem bekannten Anordnung der Wassermassen bei jeder einzelnen Serie klar hervortritt. Im einzelnen aber zeigen die gewonnenen über 20,000 Temperatur- und Salzgehaltsbeobachtungen ein ganz ausserordentlich verwickeltes und veränderliches Bild. Innerhalb einer Stunde kommen Salzgehaltsänderungen von 4 bis 6 $^0/_{00}$ vor! Die unperiodischen Änderungen sind weit grösser als sich erwarten liess. Z. B. war bei "Japetus Steenstrup" das Salzgehaltmittel für 24 Stunden anfangs 18.0, zuletzt 12.0 $^0/_{00}$; bei "Skagerak" schwankt das 24 Stundenmittel in 15 m. Tiefe zwischen 20.4 und 31.7 $^0/_{00}$!

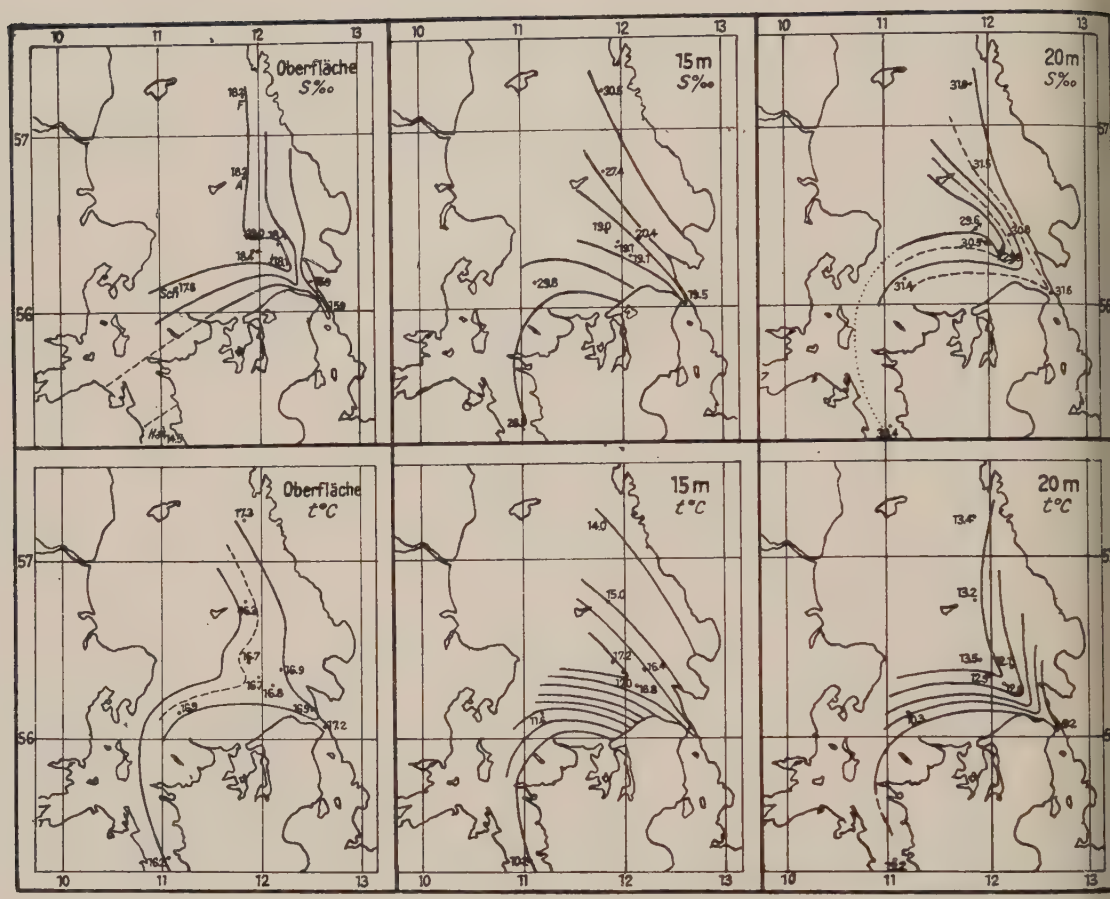


Fig. 7. Salzgehalts- und Temperaturverteilung im Kattegat am 11./12. August 1931 an der Meeresoberfläche in 15 und 20 m. Tiefe (nach v. Schubert).

Hieraus geht hervor, dass der Anteil der beiden sich im Kattegat vermischenden Wasserarten sich in kurzer Zeit sehr verändert haben muss. Es ist unmöglich, hier die Einzelheiten der Temperatur- und Salzgehaltsverteilung und ihrer Änderung zu betrachten; nach dieser Richtung muss auf die Spezialveröffentlichung selbst verwiesen werden. Nur einiges sei herausgegriffen. Um Zufälligkeiten und die Gezeitenwirkung möglichst auszuschalten sowie ausserdem die Wahrscheinlichkeit, Gesetzmässigkeiten zu finden, zu vergrössern, wurden Mittel für volle Mondtage gebildet und für diese die vertikale und horizontale Verteilung betrachtet. Hinzugenommen wurden noch die Werte von den benachbarten Feuerschiffen. Das für die Oberfläche sowie für 15 m. und 20 m. Tiefe (vergl. Fig. 7) gewonnene Bild der horizontalen Salzgehalts- und Temperaturverteilung stimmt grundsätzlich mit den vorhandenen Darstellungen der mittleren Verhältnisse überein, nach denen der Salzgehalt in der Nähe der schwedischen Küste am niedr ist, infolge des dort nach Norden setzende tischen Stromes. In den Einzelheiten zeigen die für die verschiedenen Mondtage gewo Bilder beträchtliche Abweichungen. Statt recht regelmässigen südwest-nordöstlichen Ver weisen die Isolinien starke Ausbuchtunge scharfe Kurven im Gebiete der fünf Station dass der Verlauf ausserhalb des Veranke gebietes gleichmässiger ist, liegt wohl nur dass dort nur die vergleichsweise weit ausei liegenden Feuerschiffe vorhanden sind, die heiten des Verlaufes der Isolinien also nicht werden konnten. Bei den Isolinien der Obe sind die Wirkungen des Windes auf die V bewegungen gut zu verfolgen.

In Bezug auf die vertikale Verteilung de gehaltes ist bemerkenswert, dass dort, wo Oberfläche der höchste Salzgehalt auftritt, 20 m. Tiefe, also unterhalb der Sprungschic

e findet und umgekehrt. Die Erklärung wurde in der Beeinflussung der Tiefen- Sprungschicht durch den Druck der über- n Wassermassen gefunden. Unter salz- Oberflächenwasser liegt in der Tiefe ein Maximum des Salzgehaltes, weil die chicht gehoben ist; eine zeitliche Abnahme gehaltes an der Oberfläche bedingt also Hebung der Sprungschicht eine zeitliche e des Salzgehaltes in der Tiefe. Das Um- gilt für Zunahme des Salzgehaltes an der he. Entsprechende Wirkungen auf die Lage ngschicht werden durch Deformationen der he hervorgerufen, sodass also die Wirkung asserstandserhöhung einer Vergrösserung gehaltes gleich ist und umgekehrt. Als Ur- eser Verlagerung der Sprungschicht wurden ionsbewegungen mit horizontaler Achse er- obei aber die Wirkung auf die Lage der en verschieden ist, je nachdem ob die Ver- g der Lage der Sprungschicht durch nderung der Oberfläche oder durch Ver- g des Salzgehaltes der Deckschicht ver- ist. Einen Eindruck von den bei den aufgetretenen Salzgehaltsänderungen gibt elche die Lage der Isohalinen bei "Hunte" ethen darstellt.

er den kurz angedeuteten beträchtlichen dischen Schwankungen von Temperatur und lt treten periodische Änderungen auf, von lche mit einer Dauer von 12 und 24 Mond- für den ganzen Zeitraum, solche von 14 bis lstunden Dauer zeitweise festgestellt werden Die Phasen dieser internen Wellen sich sowohl von oben nach unten wie von u Schiff stark, doch ist es gelungen, den llten Phasen durch die Annahme walzen- r Bewegungen des Wassers unter Berück- ng der Bodengestalt gerecht zu werden. Die nergebnisse der Strommessungen stützen enommenen walzenförmigen Wasserbewe- allerdings nicht; eine einwandfreie Lösung ragen ist bislang nicht gelungen.

Amplitude des täglichen Ganges der Tem- beträgt an der Oberfläche etwa 0.3°, in 5 0.1°; in 10 m. Tiefe ist sie so klein, dass handensein nicht als sicher anzusehen ist; cht in dieser Tiefe eine 12 stündige Periode

tägliche Temperaturschwankung während bachtungswoche beträgt an der Oberfläche el über ½°, mit einem Maximum um 15h nimum um 7h, in 5 m. Tiefe etwa ¼° Extremen um 19h und 6h, in 10 m. Tiefe igliche Schwankung fast verschwunden, eine ge Schwankung aber nachweisbar; diese rch Gezeitenströme verursacht sein.

festzustellenden periodischen ganztägigen ltsschwankungen sind auf den Gezeiten- ırückzuführen, ein Zusammenhang mit der

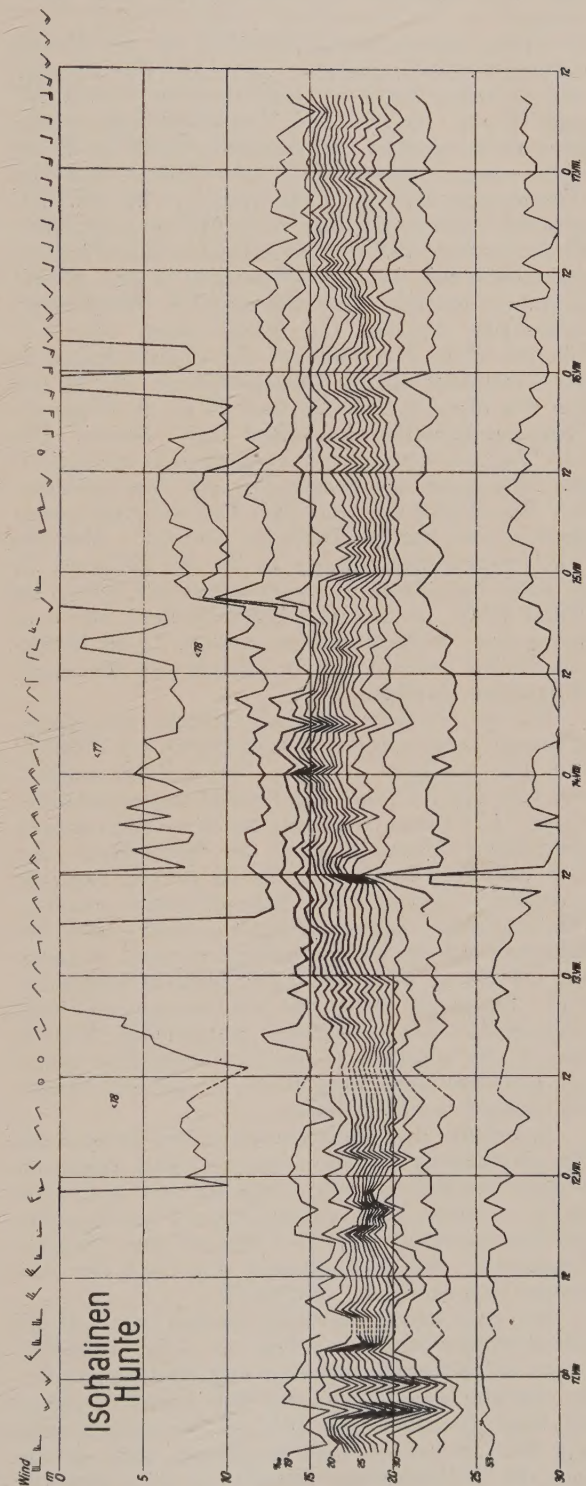


Fig. 8. Isoplethendarstellung des Salzgehaltes bei "Hunte" vom 10. bis 17. August 1931 (nach v. Schubert).

Strahlung oder der Verdunstung ist nicht nachweisbar.

Einen eingehenderen Einblick in die Veränderungen der Temperatur unterhalb der Sprungschicht ermöglichen die auf "Japetus Steenstrup" und "Hunte" ausgeführten Temperaturregistrierungen; diese wurden auf ersterem Schiff in 26 m. Tiefe vom 15. bis 17.VIII. jede Minute und von letzterem in 22.5 m. Tiefe vom 11. bis 17.VIII. teils jede zweite, teils jede vierte Minute ausgeführt. Die anlässlich der Serienmessungen auf "Hunte" gleichzeitig mit den Registrierungen in 22.5 m. mit Kipthermometern ausgeführten 137 Temperaturmessungen ergaben im Mittel einen um 0.1° höheren Wert, der wohl auf die Unsicherheiten in der Tiefenbestimmung zurückzuführen ist, da der aus den Messungen in 20 und 25 m. zu folgernde Temperaturgradient im Mittel 0.66° betrug. Die auf "Japetus Steenstrup" ausgeführten gleichzeitigen Messungen der Temperatur mit dem isolierenden Wasserschöpfer und dem Registrierinstrument ergeben eine mittlere Differenz von 0.2°. Der aus den Temperaturmessungen in 25, 26, 27 bezw. 28 m. Tiefe berechnete Temperaturgradient betrug im Mittel 0.98°, sodass die Wasserproben mit dem isolierenden Wasserschöpfer aus etwa $^1/_5$ m. kleineren Tiefen geschöpft sein dürften als die Registrierungen erfolgten.

Die zu viertelstündlichen Mitteln zusammengefassten Temperaturwerte schwankten bei "Hunte" von 9.8° bis 12.6° und bei "Japetus Steenstrup" von 6.6° bis 9.1° und die Gesamttemperaturmittel waren 11.7° bezw. 8.0°. Die aus den Temperaturen abgeleiteten Schwankungen der Tiefenlagen der 11.7 und 8.0° Isothermen waren derart, dass die Aufsuchung periodischer Schwankungen nahelag. Die Ergebnisse deuten daraufhin, dass ausser der Hauptperiode der Gezeitenbewegung noch Perioden von der Dauer $10^1/_3$ und 14.37 Stunden vorhanden sind. Die schon früher bei Strommessungen beim Feuerschiff "Lappegrunden" festgestellte Periode von ca. 4^h wurde auch in der Vertikalbewegung der Isothermfläche festgestellt, sie ist auf Seichebewegungen zurückzuführen.

Innerhalb der Viertelstunden, für welche die Temperaturmittel berechnet worden sind, traten im allgemeinen keine grossen Veränderungen auf, doch wurde in einem Falle gleichzeitig mit eintretendem Gewitter innerhalb von 3—4 Minuten bei "Japetus Steenstrup" eine Veränderung der Lage der Isotherme von ca. $^3/_4$ m. festgestellt.

Nur ganz kurz hingewiesen werden kann auf die Gezeitenuntersuchungen. Die so sehr veränderlichen und untereinander so wenig übereinstimmenden Strombeobachtungen der fünf Schiffe ergaben ein sehr gleichmässiges Bild in den abgeleiteten nur sehr schwachen Gezeitenströmen, was für die Güte der Beobachtungen spricht und zeigt, dass die früher betrachteten zeitlichen und örtlichen Unterschiede des Reststromes reel und nicht Beobachtungsfehler sind. Es gelang, eingehende Betr tungen über die vertikalen Änderungen des G tenstromes anzustellen und deren Beeinfluss durch die Reibung am Boden und an der mosphäre, weiterhin die Grösse des Reibu koeffizienten der Gezeitenströme zu bestimr Die Analyse der während der Beobachtungsper an 12 Küstenpunkten des Festlandes und der In gewonnenen Wasserstandsbeobachtungen wu eingehend analysiert. Wesentlich ergänzt wu diese Beobachtungen durch die mit dem Raus bach'schen Hochseepegel ausgeführten Wa standsaufzeichnungen. Die Diskussion dieser B achtungen war die Veranlassung zu einer Ablei der theoretischen Gezeiten des Kattegats, welche beobachteten Gezeitenerscheinungen befriedi zu erklären vermag.

Es war unmöglich, im Vorstehenden die s lichen Einzelergebnisse zu schildern, welche den einzelnen Verfassern in ausserorden mühseliger Arbeit aus den umfangreichen B achtungen abgeleitet worden sind. Es konnte nur darum handeln, jene Tatsachen und Gesi punkte hervorzuheben, welche eine Förde unserer Erkenntnis der sich im Meere abspiele Vorgänge allgemeinerer Art bedeuten. Der m dische Fortschritt der Untersuchung lag darin, *zum ersten Mal an mehreren nahe benachb Punkten synoptisch beobachtet wurde,* v wichtig ist, dass alle Beobachtungen von zuve sigen und geschulten Beobachtern ausgeführt den. In Bezug auf die Ergebnisse ist zusam fassend festzustellen dass *die unperiodis Änderungen des hydrographischen Zusta (Strom, Temperatur, Salzgehalt) an den B achtungspunkten ganz ausserordentlich viel gr waren als nach den bisherigen Kenntnissen Anschauungen zu erwarten, und es sind di Kattegat durch den Abfluss aus der Ostsee Zufluss aus der Nordsee verursachten Misch vorgänge weit intensiver und turbulenter al dahin anzunehmen war.* Ganz abgesehen von gewonnenen Erkenntnissen methodischer Art d in dieser allgemeinen Erkenntnis und Vertie unserer Auffassung der wesentliche Forts liegen. Nachträglich ist festzustellen, dass gewählte Untersuchungsgebiet wohl geeignet um zu erkennen, welch extreme Verhältniss den Mischungsvorgängen im Meere möglich es war aber wegen der ausserordentlichen Ko ziertheit der Erscheinungen ungeeignet, die schungsvorgänge quantitativ zu verfolgen. Di reichung dieses Zieles liesse sich erwarten, ein dem im südlichen Kattegat ausgeführten licher Plan in einem Teile der Nord- oder C mit einfacheren Verhältnissen, weniger inter Mischungsvorgängen und auf weitere Erstre ebenem Boden unter Nutzung der gewon Erfahrungen wiederholt würde.

Eine zweite Aufgabe, die ebenfalls nur

enarbeit mehrerer Schiffe gelöst werden
t nahegelegt durch die auf dem Schnitt
shavn—Vrangö gewonnenen Erfahrungen.
wäre es wünschenswert, an geeigneten
etwa in dem nördlichen oder südlichen
gebiet zur Nordsee hydrographische
mit Temperatur-, Salzgehalts- und Strom-
ungen so auszuführen, dass die je auf
chnitt gewonnenen Beobachtungen streng
tig erfolgen und ausserdem zu festgelegten
ten nach einigen Tagen ebenfalls gleich-
ederholt werden.
dritte, ebenfalls aus bereits früher gewon-
nd durch die Kattegatbeobachtungen bestä-

tigten Erfahrungen folgende Aufgabe, welche auch nur in internationaler Zusammenarbeit zu lösen ist, geht dahin, ein Meeresgebiet, etwa einen grösseren Teil der Nordsee oder der Ostsee durch Gewinnung zahlreicher dicht gelegener hydrographischer Stationen aufzunehmen. Dies würde in strenger Gleichzeitigkeit nicht möglich sein, wohl aber im Laufe eines Zeitraumes von wenigen Tagen.

Diese drei Aufgabenrichtungen haben gemeinsam, dass bei ihrer Durchführung das Ziel verfolgt wird, über die Mittelwert- und Stichprobenmethode hinaus und zu einer eingehenderen Erkenntnis der tatsächlichen Vorgänge zu gelangen.